The Genus *Crocus* (Liliiflorae, Iridaceae): A Descriptive Seed Morphology. Part one: Macroscopic Traits and Phylogenetic Relevance

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Abstract: *Crocus* seeds have very different macroscopic properties which are presented in detail. The main character groups like size, shape, colour, raphe, and caruncle are subdivided into 30 characteristics which were found in this comprehensive investigation of seeds of the major part of the genus and are used for a detailed description.

Zusammenfassung: Die Samen von Krokussen haben sehr unterschiedliche Eigenschaften die im Detail präsentiert werden. Die Hauptgruppen der Parameter wie Größe, Form, Farbe, „Raphe“ und „Caruncle“ werden in 30 verschiedene Charaktere unterteilt, die bei der umfassenden Untersuchung der Samen des überwiegenden Teils der Gattung gefunden wurden. Sie werden für eine detaillierte Beschreibung der Samen benutzt.

Key words: *Crocus*, seeds, macroscopic properties.

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INTRODUCTION

The presented work was initiated by the necessity for a revision of the genus *Crocus*. Recent molecular analyses (HARPKE et al. 2013) revealed many taxonomical and systematic differences, additions and novelties compared to MATHEW (1982). TURNER (1971) recognised already that “training in systematics….will be toward greater specialization” in such areas as cytogenetics, biochemistry, and computer science. This means in general a development toward a permanent increasing complexity in science which is observable almost in every field.

The growing knowledge in the genus *Crocus* is not an exception. Many new species were described since 1982 which are not determinable with the keys of that time, so there is a need for more suitable description and determination parameters (KERNDORFF et al. 2015).

Favourable in this sense would be more and rather constant macroscopic characters but this is almost illusionary in such a variable genus as *Crocus*. However, there are up to now hidden characters in some morphological “groups” which could be useful for distinguishing purposes. While studying our comprehensive living and archived material of *Crocus* we found out that several “character groups” of *Crocus* are useful under this point of view. Two very promising groups are the macro- and micromorphology of seeds.

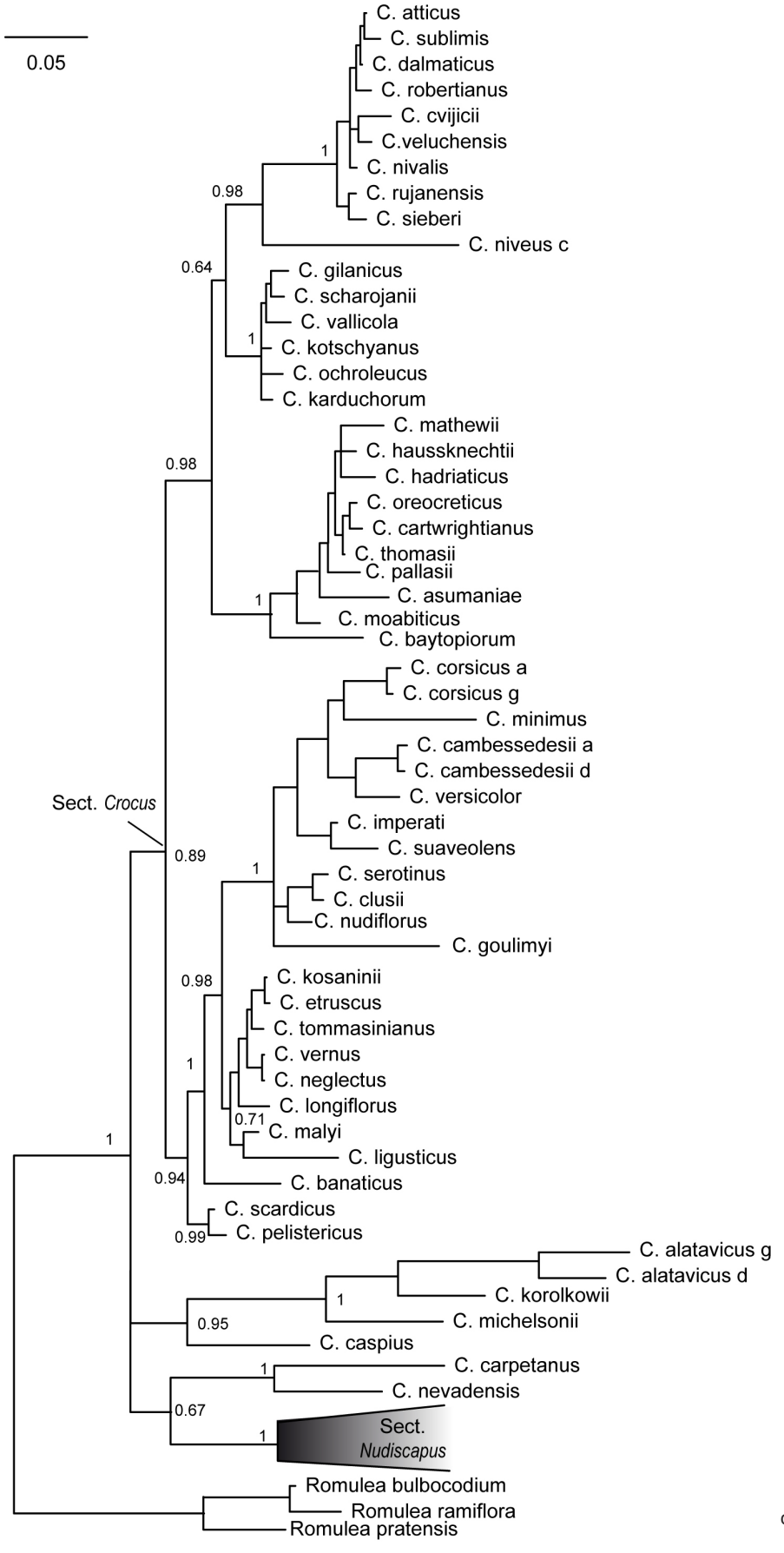

Fig. 1a: Phylogenetic tree of genus *Crocus* section *Crocus* and series *Carpetanis* and *Orientalis* species derived from a Bayesian analysis of the nrITS region. Numbers along branches give posterior probabilities.

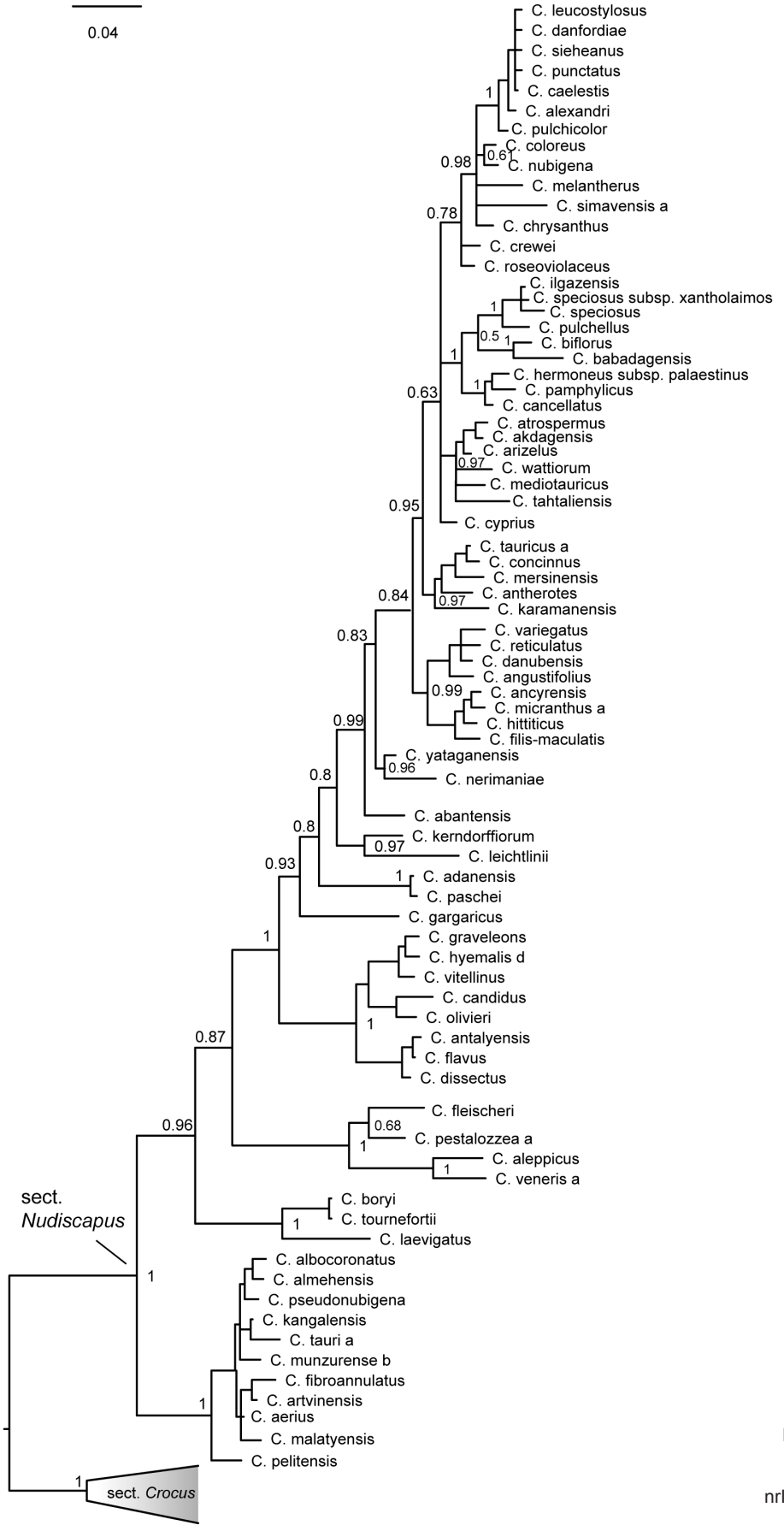

Fig. 1b: Phylogenetic tree of genus *Crocus* section *Nudiscapus* and series *Carpetanis* and *Orientalis* species derived from a Bayesian analysis of the nrITS region. Numbers along branches give posterior probabilities.

The coat of crocus seeds (testa) is in general rather hard. It is created of cellulose, hemicellulose, and pectines when the integuments (after fertilization) overgrow the micropyle. These substances thicken and strengthen the cell-walls which has an influence on survival, distribution, and germination of the seed. Traditionally the entire seed-coat is called testa. Nowadays it is differentiated between testa (outer integument) and tegmen (inner integument). Seeds of Angiosperms (e.g. *Crocus*) always have two integuments. Testa of *Crocus* seeds can be richly and very differently structured depending on species which makes them valuable for distinguishing purposes.

Characters of *Crocus* seeds are divided in the following into two categories. Macroscopic features, like size, shape, colour of testa, structure of caruncle and raphe and microscopic characters like surface structures (sculptures) and the anatomy of epidermic cells which is a matter of interest and research in "plant sciences" since a long time. Microscopic characters found using SEM will be dealt with in part two as well as a discussion and synopsis of the results of both character types.

In this paper seeds of the majority of species of the genus belonging to two sections, 24 series and several single–positioned species are presented according to their position in the recent phylogeny (Tab. 1). For most series or groups the seeds of almost all species are available. In single cases only one taxon of a series or group can be presented. Missing taxa are either explained by missing seeds or a yet unresolved systematic position of a species in the phylogeny or both. This means, the phylogenetic trees in Figs. 1a, b contain for several series or groups not all known species but only some as their representatives. Due to necessary major systematic changes in the genus many series have to be newly described or defined which is, e. g., the case for series *Reticulati* or the new series *Isauri* and *Lyciotauri*. Some new series which are not yet defined are therefore called "groups". However, this approach to the macroscopic seed characters of *Crocus* is the first systematic one, based on multi-focus seed-photographs of the majority of species presently known in the genus. In part two all findings of this survey will be statistically analysed and results checked for their taxonomical and diagnostic usability.

Molecular Phylogeny

In *Crocus*, there are two highly variable regions within the rDNA ITS sequence data set, which cannot be unambiguously aligned across the whole genus (Harpke et. al 2013). Sequences (see Harpke et al. 2013, 2014, 2015, 2016) were therefore split into two subsets and aligned manually (Figs. 1a, b).

The ITS sequences were subjected to phylogenetic analyses using Bayesian phylogenetic inference (BI) with MRBAYES 3.2 (Ronquist et. al. 2012).

For both subsets, BI 2 times 4 chains were run for 3 million generations under the appropriate models of sequence evolution (for ITS: GTR+Gamma+I; see Harpke et al. 2013, 2014, 2015, 2016), sampling a tree every 1000 generations. Converging log-likelihoods, potential scale reduction factors for each parameter and inspection of tabulated model parameters in MRBAYES suggested that stationarity had been reached in all analyses. The first 25% of trees of each run were discarded as burn-in. Two independent runs of BI analysis were performed to confirm that separate analyses converged on the same result. In each of the 2 analyses the same topology and similar posterior probabilities (pp) of nodal support resulted.

Taxonomic coverage

The systematic treatment and the taxonomy of the genus *Crocus* has presently to face a greater change due to molecular results. It is therefore not possible to present final systematic results for the time being. Despite this it is possible to present seeds of the majority of the genus' species. The taxonomic coverage of the genus in this investigation is summarized in Tab. 2. Section *Crocus* is covered with 90% of the presently known species, six series to 100%, including *C. banaticus* and *C. niveus* which occupy a special position in the phylogeny. For section *Nudiscapus* 78 % of the known and many of the new species are covered, 10 series of it to 100% (Tab. 2).

Provenance of seeds

The seeds of species listed in Tab. 1 have different origins. Chiefly to avoid artefacts we predominantly used our own seeds for photographs either wild collected or harvested from wild collected material in a time period of more than 30 years. As far as possible, seeds from types or type areas are used. In some other cases they come from institutions or other collectors (several also wild-collected), bulb firms or, rarely, from cultivated plants. Detailed information about the provenance of the investigated seeds is individually attached to every taxon in Tab. 1. Abbreviations are explained as follows: HKEP = collectors Helmut Kerndorff & Erich Pasche; HK = Helmut Kerndorff; RK = Robert Kerndorff; P = Erich Pasche; RS = collector Ruprecht Schleyer; AGS = Alpine Garden Society; EM = collector Ernst Markus;

Seed selection, preparation, and photographing

Seeds of crocus are, like all other parts of the plants, not only variable interspecifically but also individually. This can be easily seen by regarding the presented photographs (Figs. 2a-j). To get the most representative seeds of a taxon for photographing we selected them out of quite a number. We were ambitioned to select seeds with the best available condition. Of course this is not always possible and in some cases only under the microscope it became visible that, e.g., the seed is hollow or shrivelled (dried out) or covered with white hairy layers (fungi). In these cases substitutes were not available for the time being.

After harvesting, in most cases the seeds were dried for at least three month in "tea-bags". How the seeds of other collectors (collections) were treated is unknown. For photographing, three seeds of a taxon of good condition were mounted on a Petri-plate filled with a thin layer of dried Agar-Agar to avoid rolling of the seeds while moving under the microscope. Dependent on the size they were adjusted with enough individual spaces between them but within the frame of the photographs. Furthermore, for a good "round-view" of seeds they were slightly pressed down with a flexible steel tweezers into different positions on the Agar-Agar layer.

Table 1: Provenance of investigated seeds according to their position in the recent phylogeny of the genus (the number in the right column represents the internal photograph archive number which is also attached to the individual taxa names in the photographs).

Systematic position	Provenance	Photo
Without clear allocation yet (prob. to section *NUDISCAPUS*)		
series *Carpetani*		
C. carpetanus **type area**	HKEP 1559, Spain, Sierra de Guadarrama, Puerto de Navacerrada, 1850 m	426
C. nevadensis	HKEP 1203, Spain, Andalucia, Los Molinos, Sierra de Huetor, 1300-1400 m	250
series *Orientales*		
C. caspius	HKEP 1554, Iran, N of Talesh, Khotbeh-Sara,-20 m	421
C. michelsonii	HKEP 1556, Iran, Kopet dag	423
C. alatavicus	bulb firm Cambridge Bulbs, 1985/1986	085
C. korolkowii	bulb firm Potterton & Martin, seeds ex Afghanistan	087
Section *CROCUS*		
series *Scardici*		
C. scardicus	Dirk Schnabel (internal cult. no. 2014/99), ex Macedonia, Mt. Bistra	003
C. pelistericus **type area**	ex Macedonia, Mt. Pelister, Golemo Ezero, 2200 m	002
C. banaticus extra position	Botanical Garden Berlin, ex Roumania	006
C. ligusticus	HKEP 1402, Italy, Liguria, west of Varese Ligure, Comuneglia, 670 m	319
C. malyi	Dirk Schnabel (internal cult. no. 2014/99), ex Croatia, Sveti Roc, AH 8651	445
series *Verni*		
C. longiflorus	RS 1985/7, Italy, Calabria, Castrovillari, 350 m	020
C. neglectus PERUZZI & CARTA	HKEP 1401, Italy, Liguria, Varese Ligure, Passo di Cento Croci, 465 m	318
C. vernus **type area**	F.R. Blattner, Swizzerland,Gurniggel, Stierenhütte,	022
C. albiflorus KIT. EX SCHULTES	RS 1990/16, Italy, Valtournanche, 1900 m	030
C. neapolitanus (KER GAWL.) LOISEL.	Dirk Schnabel (internal cult. no. 2014/124), Italy, Monte Terminio, 1100 m	452
C. heuffelianus HERBERT	AGS seed-distribution 1990 (no. 4804)	034
C. scepusiensis BORBÁS ex KULCZ.	Mrs. B. Mikolajewiez, Poland (ex Kew/Mathew)	036
C. tommasinianus	HK 1988/5, Montenegro, Petrovac na Mouro, 200 m	017
C. etruscus **type area**	HK 1989/8, Italia, Massa Marittima, 630 m	018
C. kosaninii **type area**	HK 1988/11, Kosovo, Kacanik, 800 m	019
C. goulimyi extra position **type area**	HK 1989/35, Geece, Peloponnes, Mani, 100 m	001
series *Longiflori*		
C. nudiflorus	HKEP 1214, Spain, Pyrenees, Vielha, 1700 m	256
C. clusii GAY **type area**	HKEP 1594, Portugal, Serra de Sintra	473
C. serotinus SALISB.	HKEP 1379, Portugal, Algarve, Sagres, 30 m	317
C. salzmannii GAY **type area**	HKEP 14100, Morocco, Tetouan-Larache, Ouled Ryahi	374
series *Versicolores*		
C. suaveolens BERTOL.	HK 1989/6, Italy, Itri, 140 m	012
C. imperati	HK 1989/5, Italy, Castellamare, Mt. Faito, 1100 m	013
C. versicolor	RS 1994/3, France, Alpes Maritimes, Mt. Agel	010
C. cambessedesii	RK 1989/32, Spain, Mallorca, W of Palma, 200 m	011
C. minimus	T. Tamberg TT74/20 (Kew, Mathew), France, Corse	014
C. corsicus	B06-76-02970, Crook 2674, (ex Kew), France, Corse	015
series *Crocus*		
C. moabiticus type area	HK 1986/12, Jordan, Madaba, 700 m	047
C. asumaniae **type area**	HK 1984/11, Turkey, Akseki-Cevizli, 1200 m	040
cf. *C. pallasii*	HK 1984/3, Turkey, Honaz dağ, 1300 m	055
C. thomasii	HK 1989/2, Italy, Taranto, 20 m	045
C. cartwrightianus	HKEP 1443, Greece, Syros island, Mt. Pirghos, 390 m	332
C. oreocreticus	HK 1986/8, Geece, Crete, Lassithi, 930 m	048
C. hadriaticus	HK 1989/36, Greece, Peloponnes, Tripoli, 750 m	042
C. mathewii **type**	HKEP 9291, Turkey, Kalkan – Elmalı, 700 m	041
C. dispathaceus BOWLES	HK 1987/27, Syria, Ma'arrat an Nu'man, 540 m	039
C. macrobolbos JOVET & GOMB.	HK 1989/13, Turkey, Gaziantep, 700 m	044
series *Kotschyani*		
C. karduchorum	bulb firm Cambridge Bulbs, 8/1986	069
C. ochroleucus	bulb firm Treppens, Berlin, 10/2013	072
C. kotschyanus	HKEP 9322, Turkey, Amanus, Yarpuz, 1600 m	061
C. vallicola	M&P 8812, Turkey, Artvin, 2200 m	068
C. scharojanii	Bot. Garden Bonn (Ger), Koenen, TR-K 37.09.88	066
C. gilanicus	Wend. & Shird. 14870, Iran (ex Kew/Mathew)	071
C. k. subsp. hakkariensis	bulb firm P. & J. Christian, 9/1986, ex Turkey	063
C. suworowianus K.K OCH	Bot. Garden Bonn, Koenen, 25.07.1989, ex Turkey	064
C. niveus extra position	HK 1989/34, Greece, Peloponnes, 400 m	082
***sieberi*-group**		
C. sieberi GAY	HK 1986/2, Greece, Crete, Lefka Ori, 1500 m	073
C. rujanensis	Dirk Schnabel (internal cult. no. 2014/98), ex Serbia, Rujan Planina, 750 m	448
C. nivalis BORY & CHAUB.	Horton 1504, Greece, Mt Taygetos, (ex Mathew/Kew)	074
C. veluchensis	HKEP 1453, Bulgaria, Dobrostan, 1300 m	341
C. cvijicii	bulb firm Christian, 10/1989	081
C. robertianus	bulb firm Cambridge Bulbs, 8/1985	075
C. dalmaticus	HK 1990/15, Bosnia-Hercegovina, Trebinje, 600 m	079
C. sublimis HERBERT	Bot. Gart. Bonn, Koenen 01496	076

Table 1 (continued)

Systematic position	Provenance	Photo
Section *NUDISCAPUS*		
***adamii*-group**		
C. pelitensis **type**	HKEP 9015, Turkey, Adana, Antitaurus, 1450	098
C. malatyensis **type**	HKEP 9914, Turkey, Maden dağları, 900-1100 m	094
C. aerius **type area**	P 85115a, Turkey, Trabzon, Zigana pass, 2000 m	100
C. artvinensis **type locality**	HKEP 9359, Turkey, Artvin, Lomaşen, 350 m	095
C. fibroannulatus **type**	HKEP 9361, Turkey, Artvin, Ardanuç, 800 m	096
C. munzurense **type**	HKEP 9347, Turkey, Munzur dağları, 1000 m	101
cf. *C. tauri*	HKEP 1019, Turkey, Kop dağ Geçidi, 2350 m	102
C. kangalensis **type**	HKEP 9923, Turkey, Sivas, Kangal, 1450 m	097
cf. *C. pseudonubigena*	HK 1989/20, Turkey, Hazar Gölü, 1400 m	106
C. almehensis **type locality**	David B. Stephens, Iran, Ala2, Gorgon	093
C. albocoronatus **type**	HKEP 9009, Turkey, Antitaurus, 900 m	092
series *Laevigati*		
C. laevigatus **type area**	HKEP 1535, Greece, Kythnos island, 280 m	405
C. boryi, **type area**	HKEP 1531, Greece, Pylos-Methoni, 130 m	404
C. tournefortii	HKEP1537, Greece, Kythnos island, 240 m	407
series *Aleppici*		
C. aleppicus	HK 1985/8, Israel, Golan heights, 950 m	107
C. veneris	RK 1990/3, Cyprus, Neophytos monastery, 440 m	109
C. fleischeri	HK1983/3, Turkey, Acıpayam, 1100 m	111
C. pestalozzae	bulb firm P. & J. Christian, 1985,	113
series *Flavi*		
C. flavus	HKEP 1463, Bulgaria, Byal Izvor, 620 m	348
C. f. subsp. *dissectus* **type**	ISTE 23990, Kew/Mathew, ex Turkey	116
cf. *C. antalyensis*	HKEP1042A, TR, Antalya, Saklikent, 1400 m	117
C. olivieri	Mathew, Baytop (ex Kew), Turkey, Abant,	119
C. candidus **type area**	CMW2526, ex Kew/Mathew, Turkey, Çanakkale	123
C. vitellinus	EM 1082, Syria, Al Haffan, 500 m	121
C. graveolens	HKEP 0026, Turkey, Aladağlar, 2250	114
C. hyemalis	HK 1986/14, Jordan, Anjara, 1200 m	124
C.gargaricus extra position	HK 1984/7, Turkey, Bursa, Ulu dağ, 1900 m	130
extra position *C. paschei* **type**	HKEP 9034, Turkey, Adana, Andirin, 1100 m	126
and *C. adanensis* **type area**	HK 1989/10, Turkey, Adana, Düziçi, 1100 m	125
***kerndorffiorum*-group**		
C. leichtlinii	HK 1989/18, Turkey, Ergani, 1050	128
C. kerndorffiorum **type**	HKEP 9016, Turkey, Antitaurus, 900-1600 m	127
C. abantensis extra position	HK 1984/9, Turkey, Abant, 1600 m	129
***yataganensis*-group**		
C. nerimaniae	HKEP 0315, Turkey, Aydin, Menteşe dağları, 800 m	164
series *Reticulati*		
C. filis-maculatis **type**	HKEP 0009, Turkey, hills N of Adana, 800-1000 m	146
C. hittiticus BAYTOP & MATHEW	HK 1989/27, Turkey, Güzeloluk, 1400 m	142
C. *micranthus* **type area**	HK 1987/12, Turkey, Taurus, Gülek-Boğazı, 1100 m	176
C. ancyrensis	HKEP 0022, Turkey, Yahyalı, 1400 m	137
C. angustifolius	Ray Cobb 8/89, ex Crimea	141
C. danubensis **type**	HKEP 1344, Serbia, Negotin, 50 m	303
cf. *C. reticulatus*	Dirk Schnabel (internal cult. no. 2014/91), ex Moldavia, Bessarabia	447
C. variegatus	Dirk Schnabel (internal cult. no. 2014/115), ex Italy, Scognio/Triest, 250m	451
series *Isauri* series nova		
C. mawii **type**	HKEP 0413, Turkey, Kuyucak dağları, 1600-1700 m	198
C. rechingeri **type**	HKEP 0115, Turkey, Lycian T. Babadağ	201
C. karamanensis **type**	HKEP 0108, Turkey, Isaurian T., Karaman Prov., 1500 m	200
C. antherotes **type**	HKEP 0209, Turkey, Muğla, Madranbaba dağları, 1600 m	196
C. mersinensis **type**	HKEP 0104, Turkey, Pusatlı dağı, 1300-1400 m	199
C. concinnus **type**	HKEP 0007, Turkey, Kuyucak dağları, 1000-1800 m	197
C. tauricus **type area**	Dirk Schnabel (internal cult. no. 2014/113), ex Crimea, Tschatir Dag	450
***cyprius*-group**		
C. cyprius	RK 1990/4, Cyprus, Troodos-Mountains, 1700 m	165

Table 1 (continued)

Systematic position	Provenance	Photo
Section *NUDISCAPUS* (continued)		
series *Lyciotauri* series nova		
C. tahtaliensis **type**	HKEP 9716, Turkey, Antalya, Tahtalı Dağı 1400-1500 m	155
C. mediotauricus **type**	HKEP 0112, Turkey, Geyik Dağları, 1600-1900 m	157
C. wattiorum **type locality**	HKEP 9548, Turkey, Tahtalı dağları, 500 m	162
C. arizelus **type**	HKEP 0403, Turkey, Gölgeli dağları, 1300-1600 m	151
C. akdagensis **type**	HKEP 9721, Turkey, Ak dağı, 1500-1600 m	161
C. atrospermus **type**	HKEP 9377, Turkey, Boncuk dağları, 1500-1600 m	158
C. katrancensis **type**	HKEP 0222, Turkey, Katrancık dağı, 1600-1700 m	150
C. ziyaretensis **type**	HKEP 9820, Turkey, Ziyaret dağları, 1300-1600 m	152
C. bowlesianus **type**	HKEP 0009, Turkey, Burdur, Katrancık dağı, 1400-1500 m	153
C. calanthus **type**	HKEP 0123, Turkey, Ak dağı, 1200-1400 m	154
C. salurdagensis **type**	HKEP 9701, Turkey, Salur dağı, 1500-1600 m	160
C. oreogenus **type**	HKEP 0126 (2), Turkey, Bey dağları, 1500-1800 m	149
***cancellatus*-group**		
C. cancellatus **type area**	HKEP 0038, Turkey, Arslanköy-Konya, 2100 m	179
C. c. subsp. *pamphylicus*	HKEP 9244,Turkey, Demirtaş1580 m	182
C. c. subsp. *lycius*	HK 1988/4.1, Turkey, Korkuteli, 1100 m	188
C. damascenus HERBERT **type ar.**	HK 1987/21, Syria, Damascus, 1000 m	174
cf. *C. mazziaricus* HERBERT	HK 1985/1, Turkey, Honaz dağ, 1100 m	181
C. *hermoneus* subsp. *palaestinus*	HK 1986/13, Jordan, Salt, 850 m	183
series *Biflori*		
C. babadagensis **type**	HKEP 9708, Turkey, Lycia, Babadağ, 1200 m	159
C. biflorus **neotype**	HKEP 1307, Italy, near Prato, 340 m	281
series *Speciosi*		
C. pulchellus	bulb firm Broadleigh Gardens, 8/1985	194
cf. *C. speciosus*	HK 1987/4, TR, Taurus, Küpe dağ, 1600 m	190
C. xantholaimos	Kew/ Mathew, T. Norman, 1981, 342-78-03545	192
C. ilgazensis	Cheese, Mitchell/Watson, CMW3816, ex Kew/Mathew, 105.69.00816	193
C. roseoviolaceus	no seeds available	-
C. crewei	HK 1985/2, Turkey, Denizli, Çukurköy, 890 m	202
cf. *C. chrysanthus*	HKEP 1468**,** Bulgaria, Dagonovo-Kraishte, 800 m	350
C. melantherus	HKEP 1581**,** Geece, Langadhia, 1100 m	466
(*nubigena*-group)		
cf. *C. nubigena*	Botanical Garden Bonn (Ger), Koenen 21835	205
C. coloreus	HKEP 0314, Turkey, Aydin Dağları, 900-1000 m	156
***punctatus*-group**		
cf. *C. weldenii*	HK 1988/14, Croatia, Dubrovnik	209
C. pulchricolor	HK 1984/7, Turkey, Ulu dağ, 1700 m	221
C. alexandri **type**	Drenkovsky, Serbia, Mt. Plačkovica,Vranje (Kew/Mathew)	227
C. caelestis **type**	HKEP 0409, Turkey, Uşak, 1200-1400 m	224
C. punctatus	HKEP 9529, Turkey, Isparta, Eğridir, 980 m	207
C. sieheanus	HKEP 9002, Turkey, Çamardi, 1900 m	226
cf. *C. danfordiae*	HKEP 9920, TR, Malatya-Sivas, 1000 m	230
C. leucostylosus **type**	HKEP 0214, Turkey, Gatma dağı, 1700 m	223

The photographs were made at the Stuttgart State Museum (Germany) with a Zeiss light microscope with an EDOF camera and software of the same firm. Individual adjustments are as follows: Objective 2 x, magnification 0.57, exposure time 126 msec, saturation effect 1.35, γ 0.52. Light source was a fluorescent lamp, not a cold light source.

Macroscopic seed characters

There are comparatively few macroscopic character groups of crocus seeds which can be recognised and systematically investigated. It is the size, shape, testa condition, shape of raphe and caruncle (including a possible elaiosome), and the seed colour. Fortunately these main groups can be sub-divided into 30 different characters which we defined and used for a detailed description and comparison of the presented seeds (Tab. 3). Using these 30 characters it turned out that species of the genus *Crocus* have indeed very different seeds in many respects and present themselves in a wealth of shapes, sizes, and colours as is documented in this article. All presented seeds are described according to the character definitions in Tab. 3 and their examples presented in Fig. 4. It is noteworthy that a very detailed characterization of the seeds with the defined 30 characters in Tab. 4 was conducted

Table 2: Taxonomic coverage of investigated seeds.

Taxonomic position (no. of taxa)	**covered species**
Section *CROCUS* (59)	**53 (90%)**
series *Scardici* (2)	2 (100%)
C. banaticus extra position (1)	1 (100%)
series *Verni* (at least 10+2)	10+2 (100%)
series *Longiflori* (at least 5)	5 (100%)
series *Versicolores* (6)	6 (100%)
series *Crocus* (at least 12)	10 (83%)
series *Kotschyani* (at least 10)	8 (80%)
C. niveus extra position (1)	1 (100 %)
sieberi-group (at least 10)	8 (80%)
Without clear allocation (6)	**6 (100%)**
series *Carpetani* (2)	2 (100%)
series *Orientales* (4)	4 (100%)
Section *NUDISCAPUS* (105)	**82 (78%)**
adamii-group (at least 20)	11 (55%)
series *Laevigati* (3)	3 (100%)
series *Aleppici* (4)	4 (100%)
series *Flavi* (at least 8)	8 (100%)
C.gargaricus extra position (1)	1 (100%)
kerndorffiorum-group (2)	2 (100%)
C. abantensis extra position (1)	1 (100%)
series *Reticulati* (at least 9)	8 (89%)
yataganensis-group (2)	1 (50%)
series *Isauri* series nova (14)	7 (50%)
cyprius-group (2)	1 (50 %)
cancellatus-group (at least 6)	6 (100%)
series *Biflori* (at least 2)	2 (100%)
series *Speciosi* (at least 4)	4 (100%)
series *Lyciotauri* (at least12)	12 (100%)
nubigena-group (at least 5)	4 (80%)
punctatus-group (at least 10)	8 (80%)

Table 3: Definition of macroscopic seed characters of *Crocus*[1]

character-group	character
1 basic shape of the main seed-body[2]	1.1 globose (with sub-divisions)
	1.2 ovoid (with sub-divisions)
	1.3 elongate
	1.4 irregular shapes (chestnut-like)
2 surface condition of the main seed-body[1]	2.1 finely undulate
	2.2 coarsely undulate
	2.3 rough, linear structured
	2.4 rough, without structure
	2.5 smooth
3 raphe	3.1 indistinct
	3.2 distinct
	3.3 prominent & winged
4.1 caruncle as broad extension of the main seed-body	4.1.1 ends half-round
	4.1.2 ends tongue-shaped
	4.1.3 ends conical
4.2 caruncle as separate part of the main seed-body	4.2.1 indistinct
	4.2.2 caruncle of different colour compared to main-body
	4.2.3 knob-shaped
	4.2.4 sac-shaped
	4.2.5 tongue-shaped
	4.2.6 hood-shaped
	4.2.7 horn-shaped
5 elaiosome	5.1 absent
	5.2 present (as caruncle)
	5.3 present (attached to raphe)
6 shape of the seed end opposite to the caruncle	6.1 rounded
	6.2 peaky
	6.3 knob-like
	6.4 sac-like
	6.5 conical

[1]sizes and colors will be dealt with separately
[2]seed without caruncle and/or raphe

to receive a maximum of information. The arrangement of the taxa in the descriptions of Tab. 4 is according to the phylogenetic position in Figs. 1a, b.

The **size** of the seeds we define here for the length and width of the "main body" as can be seen in Fig. 3 because in some cases the caruncle can be almost half of the size of the seed which would result in wrong size values if considered. The size of the main-body can vary considerably from about 1 to almost 5 mm in diameter. The measurements were taken under a microscope using a magnification of around 50times, calibrated with an accuracy of 1µm, rounded in the presented results of table 3 to 0.1 mm.

The **shape** of the main body (Figs. 4, 1.1-1.4) can be globose, ovoid, "elongated", and rather irregularly shaped ("chestnut-formed"). All kinds of transitions or special forms existing are mentioned or described in detail.

The **surface of the testa** can be finely undulated (Fig. 4, 2.1), coarsely undulated (Fig. 4, 2.2), rough linear structured (Fig. 4, 2.3), rough without structure (Fig. 4, 2.4) and smooth (Fig. 4, 2.5)

The **raphe**, a longitudinal ridge on the outer seed-coat, always present in crocus seeds can have different kinds of developments. In few cases it is almost invisible (Fig. 4, 3.1), but in most cases it is distinct (Fig. 4, 3.2) or even prominent with wings (Fig. 4, 3.3). Like with all the other parameters there are many kinds of transitional forms.

The **caruncle** is a horny outgrowth near the hilum of the seed and is formed from the integuments. It can be almost half of the size of the seed or rather indistinct as a little knob at one longitudinal end of the seed. We differentiate between two basic kinds of caruncles, a) as an extension of the seed-body in its dimension with half-rounded (Fig. 4, 4.1.1), tongue-shaped (Fig. 4, 4.1.2), and conical ends (Fig. 4, 4.1.2), or b) as a separate and normally smaller part grown like an appendage to the main seed-body (Figs. 4, 4.2.3-4.2.7), both with different shapes at their ends. Also, the colour of the caruncle compared to the main-body can be different (Fig. 4, 4.2.2).

The **elaiosome** ("oil-body") is a nutrient-rich soft attachment to the seed which is attractive to ants (myrmecophily).

Table 4: Description of macroscopic seed characteristics of *Crocus*.

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
Without clear allocation yet (prob. to section *NUDISCAPUS*)								
series *Carpetani*								
C. carpetanus **type area**	ovoid, partly irregulary	1.8-2.2 • 1.4-1.9	rough, partly smooth, without structure	Cadmium red purple variation	distinct, extended at caruncle	prominent, as elaiosome	present, prominent (as caruncle), light yellow	rounded
C. nevadensis	globose to subglobose	2.0-2.3 • 1.8-2.1	rough, partly smooth, without structure	Mars Brown variation	distinct, extended at caruncle	prominent, as elaiosome	present, prominent (as caruncle), light yellow	rounded
series *Orientales*								
C. caspius	ovoid, partly irregularly half-moon-shaped	2.7-3.3 • 2.1-2.8	coarsely undulate	Dark manganese violet variation	mostly indistinct	indistinct, knob-shaped	partly present as caruncle, indistinct	knob-like to peaky (small and indistinct)
C. michelsonii	Irregularly ovoid to half-moon shaped	2.3-3.0 • 2.0-2.6	coarsely undulate	Dark manganese violet variation	indistinct	indistinct	absent or indistinct (as caruncle)	rounded or rarely slightly peaky
C. alatavicus	ovoid	2.0-3.0 • 1.8-2.5	coarsely undulate	Burnt umber variation	distinct	prominent, as elaiosome	present, prominent (as caruncle) golden-yellow	rounded to knob-like
C. korolkowii	ovoid to sub-globose, often flattened at side of caruncle	2.7-3.2 • 2.4-2.8	coarsely undulate	Burnt umber variation	indistinct	indistinct	absent	rounded
Section *CROCUS*								
series *Scardici*								
C. scardicus	ovoid to irregularly shaped	2,6-2.9 • 1.8-2.1	rough, without structure	Mars Brown variation	distinct	indistinctly sac-shaped	absent	knob-like
C. pelistericus	elogate	3.4-3.6 • 1.3-1.4	rough, without structure	Burnt umber variation	distinct	indistinctly sac-shaped	absent	knob-like
***C. banaticus* extra pos.**	globose to slightly ovoid	2.2-2.7 • 2.0-2.4	rough, without structure	Mars Brown variation	prominent, towards the end significantly winged	sac-shaped	absent	knob-like
series *Verni*								
C. ligusticus extra pos.	globose to irregularly shaped	2.0-2.2 • 2.0-2.5	rough, without structure	Cadmium red purple variation	distinct to prominent, sometimes winged	indistinctly sac-shaped	absent	knob-like
C. malyi extra pos.	sub-globose to ovoid	2.7-3.0 • 2.3-2.9	rough, without structure	Cadmium red purple variation	distinct and often winged	indistinct, sac-shaped	absent	knob-like (small)
C. longiflorus	sub-globose, ovoid, irregular	1.5-1.9 • 1.8-2.2	rough, without structure	Mars Brown variation	mostly distinct, rarely winged	indistinct, sac-shaped	absent	knob-like (small)
C. neglectus	mainly irregular, rarely sub-globose or ovoid	2.2-2.4 • 1.8-2.3	smooth to rough without structure	Yellow ochre half burnt	distinct, sometimes winged	indistinct, sac-shaped	absent	knob-like (small)
C. vernus	sub-globose to ovoid, rarely irregular	2.1-2.8 • 1.8-1.9	rough without structure to smooth	Mars Brown variation	distinct	indistinct	absent	rounded or peaky (short)
C. albiflorus	sub-globose to ovoid, often irregular	1.6-2.2 • 1.6-1.8	rough without structure to smooth	Burnt sienna variation	distinct, occasionally winged at one end	indistinct	absent	rounded or peaky (short)
C. neapolitanus	sub-globose to ovoid	1.9-2.2 • 1.8-2.0	rough without structure to smooth	Cadmium red purple variation	distinct	indistinct	absent	mainly peaky (short)
C. heuffelianus	sub-globose to ovoid, flattened at caruncle	1.9-2.3 • 1.6-2.2	rough without structure	Italian earth with brilliant yellow	distinct	knob- or small sac-shaped	absent	peaky (short)

Table 4 (continued)

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
series *Verni* (continued)								
C. scepusiensis	sub-globose to ovoid or irregularly shaped	1.7-2.6 • 1.7-2.3	rough, without structure	Raw umber with yellow ochre variation	indistinct to distinct	knob- or small sac-shaped	absent	peaky or knob-shaped (short)
C. tommasinianus	mainly globose, rarely ovoid	1.9-2.2 • 1.6-2.2	rough, without structure	Brown ochre with naples yellow variation	distinct, sometimes winged	knob-like	absent	knob-like (small)
C. etruscus	sub-globose to ovoid, raely irregular	1.7-2.3 • 1.8-2.1	rough, without structure	Burnt sienna variation	distinct, sometimes winged	small, sac-shaped	absent	short, peaky
C. kosaninii	globose to ovoid rarely somewhat irregular	2.3-2.4 • 1.9-2.4	rough without structure to smooth	Raw umber with yellow ochre variation	distinct, sometimes winged	small, knob-shaped	absent	rounded or peaky (short)
***C. goulimyi* extra position**	globose to sub-globose	3.0-3.4 • 2.8-3.3	rough, without structure	Burnt sienna variation	indistinct	indistinct	absent	rounded, rarely peaky
series *Longiflori*								
C. nudiflorus	ovoid, flattened at caruncle	2.1-2.5 • 1.7-1.9	rough, without structure	Red umber variation	distinct, often winged and broadened at end	sac-shaped	absent	sac-shaped to peaky
C. clusii	globose to ovoid, often flattened at caruncle	1.2-1.6 • 1.4-1.6	rough without structure to smooth	English red with flesh tint	distinct	sac-shaped	absent	rounded or peaky
C. serotinus	ovoid to irregularly shaped	1.2-1.9 • 1.3-1.6	rough without structure or smooth	Burnt sienna variation	indistinct to distinct	caruncle often of a different colour and extension of main-body, horn-like to conical	absent	rounded or peaky
C. salzmannii	ovoid, often flattened at one side	2.4-3.4 • 2.0-2.5	coarsely undulate	Mars Brown variation	indistinct	indistinctly sac-like	absent	rounded
series *Versicolores*								
C. suaveolens	mainly ovoid, rarely sub-globose	2.1-2.5 • 1.8-2.1	rough, without structure, glossy	Burnt sienna variation	distinct, broadened at end	sac-like of bright yellow colour	caruncle may function as elaiosome	rounded or slightly peaky
C. imperati	globose to ovoid	1.7-2.3 • 1.6-2.1	coarsely undulate to rough without structure	Mars Orange-red	distinct, broadened at end	broadly sac-like mostly of bright yellow colour	caruncle may function as elaiosome	rounded or slightly peaky
C. versicolor	ovoid	2.3-2.7 • 1.9-2.3	rough, without or with linear structure	Red umber variation	distinct, sometimes broadened at end	sac-like	absent	rounded, rarely peaky
C. cambessedesii	globose to sub-globose,	1.3-1.5 • 1.4-1.5	rough, without structure, glossy	Raw umber with yellow ochre variation	distinct, broadened at end	sac-like with brighter colour as main-body	caruncle may function as elaiosome	rounded, rarely slightly peaky
C. minimus	globose to sub-globose	1.5-1.7 • 1.3-1.4	rough without structure	Red umber with yellow ochre variation	distinct	indistinct, knob-like	absent	rounded or slightly knob-like
C. corsicus	sub-globose to ovoid	1.9-2.3 • 1.8	rough without structure, glossy	Burnt umber variation	distinct, broadened at end	broadly sac-like of light brownish colour	caruncle may function as elaiosome	rounded
series *Crocus*								
C. moabiticus	globose to ovoid, sometimes flattened	2.5-2.8 • 2.0-2.6	rough without structure	Red umber with yellow ochre variation	distinct, slightly winged	indistinct	absent	little knobs or peaks
C. asumaniae	globose to ovoid	2.7-3.4 • 2.6-2.7	rough without structure	Yellow ochre with burnt umber variation	prominent, often with extended wings	sac-like of different sizes	extended raphe may function as elaiosome	knobs or peaks

Table 4 (continued)

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
series *Crocus* (continued)								
C. pallasii	globose to ovoid	3.0-3.8 • 2.4-2.7	rough without structure	Red umber with yellow ochre variation	prominent and winged, extended at apex	sac- to knob-like	extended raphe may function as elaiosome	little knobs or peaks
C. thomasii	sub-globose to ovoid and irregular shapes	1.9-2.3 • 1.5-2.0	rough without structure	Brown ochre with naples yellow variation	distinct to prominent, often winged at apex	sac-like of different sizes	absent	indistinct, small knobs or peaks
C. cartwrightianus	globose to ovoid	2.1-2.6 • 2.0-2.5	rough without structure	Burnt umber variation	distinct but rarely winged	sac-shaped of very different sizes	sacs may function as elaiosome	little knobs or peaks
C. oreocreticus	globose to ovoid, sometimes flattened	2.6-3.3 • 2.1-2.8	rough without structure	Red umber with yellow ochre variation	prominent and winged, extended at apex	indistinct to knob-like	extended raphe may function as elaiosome	little knobs or peaks
C. hadriaticus	globose to ovoid or unregularly shaped	2.7-2.8 • 2.4-2.8	rough without structure	Red umber with yellow ochre variation	distinct, often extended at apex	sac- to knob-like	absent	small knobs or peaks
C. mathewii	globose to sub-globose	2.8-3.4 • 2.7-3.3	rough without structure	Red umber with yellow ochre variation	prominent, rarely winged at apex	knob-like, rarely sac-like	absent	knobs or rarely peaks
C. dispathaceus	globose to ovoid	2.6-3.3 • 2.4-3.1	rough without structure	Mars yellow with Italian earth	prominent, extended wings	indistinct, sac-like	absent	very little knobs or peaks
C. macrobolbos	globose to ovoid	2.3-2.8 • 2.1-2.7	rough without structure	Yellow deep with ochre	distinct and winged, extended at apex	sac-like of different sizes	extended raphe may function as elaiosome	indistinct, small knobs
series *Kotschyani*								
C. karduchorum	globose to sub-globose, often flattened at caruncle	1.6-1.9 • 1.7-1.9	mainly smooth	Red umber variation	distinct, ridge-like	indistinct to knob-shaped	absent	very little knobs or peaks
C. ochroleucus	globose to sub-globose, often flattened at caruncle	1.8-2.3 • 1.9-2.1	rough without structure or finely undulate	Brown ochre with naples yellow variation	mostly indistinct	indistinct to knob-shaped	absent	rounded or very little knobs or peaks
C. kotschyanus	sub-globose, ovoid or with irregular shape, flattened at caruncle	1.7-2.4 • 1.8-2.0	smooth to slightly rough without structure	Mars Brown variation	indistinct to a rather distinct ridge, apex often yellowish	knob-shaped	yellowish apex of raphe may function as elaiosome	rounded or little knobs
C. vallicola	sub-globose or irregularly so, flattened at caruncle	1.5-1.7 • 1.5-1.7	smooth to slightly rough without structure	Mars Brown variation	indistinct to distinct, rarely with slight extension	indistinct to knob-shaped	absent	rounded or little knobs
C. scharojanii	sub-globose, ovoid or with irregular shape, flattened at caruncle	1.6-2.0 • 1.3-1.8	rough without structure	Raw umber variation	indistinct to rarely distinct	indistinct to knob-shaped	absent	rounded or little knobs
C. gilanicus	sub-globose, flattened at caruncle	2.0-2.3 • 2.0-2.5	rough without structure	Mars Brown variation	distinct ridges, rarely with tiny yellow extensions at apex	knob-shaped	apex of raphe may function as elaiosome	rounded or knobs
C. hakkariensis	sub-globose to ovoid, flattened at caruncle	1.9-2.4 • 1.8-2.4	rough without structure	Red umber with yellow ochre variation	distinct ridges, extended at apex	knob- to sac-like	apex of raphe may function as elaiosome	little knobs
C. suworowianus	rarely globose, mostly ovoid, flattened at caruncle	1.7-2.1 • 1.3-1.7	rough without structure	Red umber with yellow ochre variation	distinct ridges, sometimes with slight yellow extensions at apex	knob-shaped	apex of raphe may function as elaiosome	rounded or knobs
***C. niveus* extra position**	sub-globose to ovoid, flattened at caruncle	2.7-3.3 • 2.4-2.8	rough without structure	Mars Brown variation	distinct ridges	knob-shaped	absent	little knobs

Table 4 (continued)

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
***sieberi*-group**								
C. sieberi	sub-globose, ovoid or with irregular shape	1.8-2.3 • 1.3-1.9	rough without structure, glossy	Raw umber variation	distinct ridges significantly expanded at end into a golden-yellow skinny elaiosome	indistinct to knob-shaped	present (attached to raphe)	rounded
C. rujanensis	globose to ovoid	1.8-2.4 • 1.9-2.1	rough without structure	Caput mort violet (mars) variation	distinct ridges expanded at end into a very prominent golden-yellow skinny elaiosome	shortly knob- or sac-shaped	present (attached to raphe)	little peaks but mostly hidden under elaiosome
C. nivalis	ovoid	1.5-2.6 • 1.3-2.4	rough without structure, sometimes glossy	Mars Brown variation	distinct ridges often winged significantly expanded at end into a golden-yellow skinny elaiosome	knob-shaped or shortly tongue-like	present (attached to raphe)	indescribable (hidden under the elaiosome)
C. veluchensis	sub-globose, ovoid or with irregular shape	1.2-1.5 • 1.1-1.3	rough without structure	Mars Brown variation	distinct ridges expanded at end into a bright yellow skinny elaiosome	mainly extended knob-shaped	present (attached to raphe)	peaky but often hidden by elaiosome
C. cvijicii	ovoid	2.4-2.6 • 1.7-1.8	rough without structure	Mars Brown variation	distinct ridges expanded at end into a brownish-yellow skinny elaiosome	shortly knob- or sac-shaped	present (attached to raphe)	rounded
C. robertianus	sub-globose to ovoid	1.9-2.4 • 1.8-2.1	rough without or (occas.) with linear structures	Mars Brown variation	distinct ridges expanded at end into a golden-brownish skinny elaiosome	knob-shaped or shortly tongue-like	present (attached to raphe)	rounded or very small knobs or peaks
C. dalmaticus	globose to ovoid	1.8-2.2 • 1.6-2.1	rough without structure	Burnt umber variation	distinct ridges expanded at end into a yellow-brownish skinny elaiosome	distinct, sac- or shortly tongue-shaped	present (attached to raphe)	indescribable (hidden under the elaiosome)
C. sublimis	sub-globose to mainly ovoid	1.8-2.6 • 1.5-1.8	rough without structure	Mars Brown variation	ridges rather indistinct but expanded at end into a bright yellow skinny elaiosome	indistinct or shortly knob-shaped	present (attached to raphe)	rounded
Section *NUDISCAPUS*								
***adamii*-group**								
C. pelitensis	elongated	2.2-2.7 • 1.0-1.3	rough without or with slight linear structures	Mars Brown variation	prominent, ridge-like, extended near caruncle	prominent, sac-shaped	caruncle may function as elaiosome	mostly rounded or little knobs
C. malatyensis	mainly ovoid	2.2-2.8 • 1.6-1.9	rough without structure	Brown ochre with naples yellow variation	rather indistinct, rarely ridge-like	prominent, sac-shaped of different colour compared to main body	caruncle may function as elaiosome	rounded or little knobs
C. aerius	ovoid, flattened at caruncle	2.0-2.2 • 1.6-1.7	rough without structure	Burnt umber variation	distinct, extended at caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded or tiny flat knobs
C. artvinensis	mainly ovoid	1.9-2.0 • 1.4-1.8	finely to roughly undulate	Mars Brown variation	mostly a distinct ridge	prominent, sac-shaped	caruncle may function as elaiosome	little knobs or rarely peaks

Table 4 (continued)

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
***adamii*-group** (continued)								
C. fibroannulatus	mainly ovoid	1.8-2.3 • 1.6-1.7	rough without structure	Raw umber variation	prominent, ridge-like, often winged near caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded or little knobs
C. munzurense	ovoid	2.1-1.2	coarsely undulate	Yellow ochre with burnt umber variation	probably distinct, ridge-like (only 1 seed)	very prominent, sac-shaped	caruncle may function as elaiosome	rounded or tiny flat knobs
C. tauri	ovoid or irregularely shaped	1.9-2.5 • 1.5-2.1	rough without or with slight linear structures	Raw umber variation	ridge-like but often indistinct	prominent, sac-shaped	caruncle may function as elaiosome	rounded or tiny flat knobs
C. kangalensis	globose to ovoid	1.9-2.2 • 1.5-1.8	rough without structure	Raw umber variation	prominent, ridge-like, extended near caruncle	prominent, sac-shaped	caruncle may function as elaiosome	mostly rounded or very little knobs
C. pseudonubigena	ovoid	1.8-2.2 • 1.6-1.9	coarsely undulate	Brown ochre with naples yellow variation	distinct, low ridges	prominent, as extension of main-body	caruncle may function as elaiosome	rounded or rarely knob-shaped
*C. almehensis**	globose?	1.95 • 1.82	rough without structure	Red umber with yellow ochre variation	rather indistinct	prominent, sac-shaped	caruncle may function as elaiosome	little knobs
C. albocoronatus	globose, ovoid or with irregular shape	2.7-3.1 • 2.1-2.3	rough without structure	Raw umber with yellow ochre variation	mostly rather indistinct sometimes slightly extended at apex	prominent, sac-shaped	caruncle may function as elaiosome	mainly rounded
series *Laevigati*								
C. laevigatus	globose or irregularly shaped, flattened at caruncle	1.5-1.8 • 1.5-1.8	rough without structure	Caput mort violet (mars) variation	ridges, often indistict	knob-shaped	absent	rounded, knob-shaped or peaky
C. boryi	ovoid	1.7-1.9 • 1.4-1.5	rough without structure to finely undulate	Cadmium red purple variation	rather indistinct	prominent as extension of main-body, differently coloured, tongue- or horn-shaped	absent	rounded or very little peaks
C. tournefortii	globose to sub-globose, flattened at caruncle	1.5-2.1 • 1.7-2.0	rough without structure	Cadmium red purple variation	indistinct, rarely tiny ridges extended at caruncle	prominent and/or as extension of main-body, tongue- or horn-shaped	absent	rounded or rarely tiny peaks
series *Aleppici*								
C. aleppicus	globose to sub-globose	1.7-2.2 • 1.7-2.0	coarsely undulate	Burnt umber variation	distinct ridges extended at caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded or knob-shaped
C. veneris	sub-globose to ovoid	1.9-2.1 • 1.8-2.2	coarsely undulate	Raw umber variation	distinct ridges extended at caruncle	prominent, sac- to horn-shaped	caruncle may function as elaiosome	rounded
C. fleischeri	sub-globose to ovoid	1.9-2.4 • 1.4-2.1	coarsely undulate	Raw umber variation	distinct ridges extended at caruncle	prominent, sac-shaped	caruncle may function as elaiosome	knob-shaped
C. pestalozzae	globose to subglobose, flattened at caruncle	1.5-1.7 • 1.4-1.6	rough or coarsely undulate	Mars Brown variation	indistinct, rarely low ridges	indistinct to slightly knob-shaped	absent	rounded
series *Flavi*								
C. flavus	mostly irregular, rarely sub-globose	1.3-1.6 • 1.1-1.6	rough without structure	Mars Brown variation	distinct ridges extended to an elaiosome at opposite end of caruncle	prominent, sac-shaped	present	peaky to knob-like of light yellow colour

Table 4 (continued)

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
series *Flavi* (continued)								
C. f. dissectus	ovoid	1.7-1.9 • 1.1-1.6	rough without structure	Mars Brown variation	distinct ridges extended to a skinny yellowish elaiosome at opposite end of caruncle	prominent, sac-shaped	present	knob- to sac-shaped of yellowish colour
C. antalyensis	ovoid	1.9-2.2 • 1.6-1.8	coarsely undulate	Brown ochre with naples yellow variation	very prominent swollen ridges	distinct, sac-shaped	ridges may function as elaiosome	knob- to sac-shaped
C. olivieri	mainly elongated	2.2-3.1 •	rough without structure	Burnt umber variation	indistinct to distinct, if so then extended at caruncle	distinct, often as extended main-body, rounded or tongue-shaped	caruncle may function as elaiosome	rounded or slightly peaky
C. candidus	extended ovoid to irregularly ovoid	2.1-2.2 • 1.5-1.7	rough to coarsely undulate	Burnt umber variation	indistinct to distinct ridges extended at caruncle	distinct, as extended main-body, half-rounded or tongue-shaped	caruncle may function as elaiosome	rounded or rarely slightly peaky
C. vitellinus	ovoid	1.8-1.9 • 1.4-1.7	rough to coarsely undulate	Mars Brown variation	indistinct to distinct ridges extended at caruncle	distinct, often as extended main-body, half-rounded or tongue-shaped	caruncle may function as elaiosome	prominent, knob-shaped
C. graveolens	ovoid to elongate	2.4-3.1 • 1.4-2.0	rough without structure	Burnt umber variation	indistinct to distinct ridges extended at caruncle	distinct, often as extended main-body, half-rounded or tongue-shaped	caruncle may function as elaiosome	prominent, mostly conical
C. hyemalis	sub-globose	2.2 • 2.4	coarsely undulate	Raw umber variation	indistinct ridges	indistinct	absent	rounded
extra position *C. gargaricus*	globose to sub-globose	1.6-1.9 • 1.4-2.0	smooth to rough without structure	Brown ochre with naples yellow variation	indistinct to distinct ridge expanded at apex into a bright yellow membrane	indistinct or small knob-shaped	expanded apex of raphe may function as elaiosome	rounded
extra position *C. paschei*	sub-globose, ovoid or irregularly shaped, often flattened at caruncle	2.2-2.5 • 2.0-2.2	rough without structure	Raw umber variation	distinct ridge merged into caruncle	very distinct, sac-shaped	caruncle may function as elaiosome	rounded or little peaks
C. adanensis	ovoid, often flattened at caruncle	1.8-2.3 • 1.5-1.6	rough, linear structured	Red umber with yellow ochre variation	indistinct to distinct bright skinny ridge extended at caruncle	distinct, sac-shaped	caruncle may function as elaiosome	knob-shaped
***kerndorffiorum*-group**								
C. kerndorffiorum	elongate	2.4-2.7 • 1.3-1.5	coarsely undulate	Yellow ochre with burnt umber variation	mainly a distinct ridge, extended at caruncle	prominent, sac-shaped	caruncle may function as elaiosome	knob-shaped
C. leichtlinii	ovoid or irregularly shaped, flattened at caruncle	1.7-1.9 • 1.1-1.6	coarsely undulate	Raw umber with yellow ochre variation	distinct ridge, extended at caruncle	mostly prominent, knob- to sac-shaped	caruncle may function as elaiosome	rounded or slightly peaky
***C. abantensis* extra position**	ovoid to elongate sometimes irregularly curved	2.1-2.2 • 1.1-1.2	coarsely undulate	Burnt umber variation	distinct ridge, extended at caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded, little peaks or knobs
***yataganensis*-group**								
C. nerimaniae	ovoid, sometimes flattened at caruncle	1.9-2.2 • 1.4-1.6	rough, with linear structures and/or finely undulate	Red umber with yellow ochre variation	distinct ridges broadened at caruncle	prominent, sac-shaped often as extension of main-body	caruncle may function as elaiosome	knob-like

Table 4 (continued)

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
series *Reticulati*								
C. variegatus	sub-globose to ovoid	2.2-2.5 • 2.0-2.1	rough without structure	Raw sienna with yellow deep variation	prominent ridge, often swollen, extended into caruncle	prominent, sac-shaped often as extension of main-body	caruncle may function as elaiosome	rounded or flat knobs
C. reticulatus cf.	sub-globose to ovoid	2.4-2.8 • 1.9-2.4	rough without structure	Mars Brown variation	distinct to prominent extended into caruncle	prominent, sac-like mostly as extension of main-body	caruncle may function as elaiosome	rounded
C. danubensis	globose to ovoid, shape often hidden by skinny swollen structures	1.5-1.9 • 1.4-1.6	mainly rough without structure	Raw sienna with yellow deep variation	distinct to prominent of yellowish colour extended into caruncle	prominent as extension of main-body, same colour as raphe	caruncle may function as elaiosome	knob-shaped or rounded
C. angustifolius	sub-globose to ovoid, often flattened at caruncle	1.9-2.4 • 1.8-2.1	rough to slightly undulate	Mars Brown variation	distinct to prominent, extended into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded
C. ancyrensis	ovoid	2.0-2.1 • 1.4-1.6	rough without structure	Raw umber with yellow ochre variation	prominent ridges, extended into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	little knobs
C. *micranthus*	ovoid to extended ovoid	2.4-2.8 • 1.5-1.7	coarsely undulate	Yellow ochre with burnt umber variation	prominent skinny ridg-es, broadened at apex into knobs or sacs	prominent, sac-shaped	present	end of raphe may function as elaiosome
C. hittiticus	sub-globose to ovoid	1.4-1.7 • 1.3-1.5	rough or finely undulate	Brown ochre with naples yellow variation	distinct ridges, extended sac-like at apex	prominent, sac-shaped	present	end of raphe may function as elaiosome
C. filis-maculatis	significantly elongated	3.3-3.6 • 1.2-1.4	rough linear structured	Red umber with yellow ochre variation	low ridges, broadened when merged into caruncle	prominent, of diffe-rent color, tongue- to horn-shaped	caruncle may function as elaiosome	mainly knob-like
series *Isauri*								
C. mawii	ovoid to irregularly shaped	1.5-2.1 • 1.2-1.6	smooth, rough or undulate	Mars Brown variation	mostly distinct fleshy ridges merged into caruncle	extremely prominent as extension of main-body	caruncle may function as elaiosome	knob-shaped or peaky
C. rechingeri	of presently available material **n**ot **d**eterminable	n.d.	probably undulate	Mars Brown variation	n.d.	obviously sac-shaped	n.d.	n.d.
C. karamanensis	sub-globose, ovoid or irregular shaped	2.1-2.3 • 1.7-2.0	rough to finely undulate	Red umber with yellow ochre variation	distinct ridges merged into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	knob-like
C. antherotes	globose to ovoid	1.9-2.2 • 1.6-1.9	rough, finely or coarsely undulate	Raw umber variation	indistinct to distinct ridges	prominent, sac-shaped often as large exten-sion of main-body	caruncle may function as elaiosome	rounded or knob-like
C. mersinensis	sub-globose or irregularly shaped	1.4-1.8 • 1.5-1.8	rough without structure	Red umber variation	fleshy ridges, extended into caruncle	prominent, sac-shaped often as extension of main-body	caruncle may function as elaiosome	rounded or little peaks
C. concinnus	ovoid, flattened at caruncle	2.2-3.0 • 1.7-2.3	rough or finely to coarsely undulate	Mars Brown variation	distinct ridges, partly winged, extended into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	low knobs or sacs
C. tauricus	globose to sub-globose	2.3-2.7 • 2.2-2.9	rough to undulate	Dark manganese violet variation	mostly distinct fleshy ridges merged into caruncle	very prominent, sac-shaped or ends half-rounded	caruncle may function as elaiosome	knob-shaped
C. cyprius	ovoid	1.7-2.2 • 1.4-1.6	coarsely undulate	Raw umber with yellow ochre variation	distinct to prominent, often fleshy, merged into caruncle	very prominent, sac-shaped	caruncle may function as elaiosome	rounded or little knobs

Table 4 (continued)

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
series *Lyciotauri*								
C. tahtaliensis	sub-globose to ovoid	1.8-2.3 • 1.6-2.2	coarsely undulate	Raw umber variation	distinct fleshy ridges, extended when merged into caruncle	distinct, sac-shaped	caruncle may function as elaiosome	rounded or small knobs
C. mediotauricus	sub-globose to ovoid	2.3-2.9 • 1.9-2.2	rough to coarsely undulate	Red umber variation	distinct fleshy ridges, extended when merged into caruncle	distinct, sac-shaped	caruncle may function as elaiosome	rounded or tiny peaks
C. wattiorum	globose to ovoid	2.0-2.5 • 1.7-1.9	rough without structure	Brown ochre with naples yellow variation	distinct fleshy ridges, merged into caruncle	tongue-shaped	caruncle may function as elaiosome	rounded or little peaks
C. arizelus	sub-globose to irregularly shaped, flattened at caruncle	1.6-2.1 • 1.5-1.9	rough, sometimes with linear structures	Burnt umber variation	indistinct	sac-shaped	caruncle may function as elaiosome	rounded or flat knobs
C. akdagensis	globose to sub-globose	2.3-2.4 • 2.2-2.4	coarsely undulate	Raw umber variation	distinct fleshy ridges, merged into caruncle	distinct, sac-shaped	caruncle functions as elaiosome	rounded or tiny knobs
C. atrospermus	globose to ovoid	2.0-2.3 • 1.7-2.2	coarsely undulate	Raw umber variation	rather fleshy ridges, extended into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded or little knobs
C. katrancensis	sub-globose to ovoid, flattened at caruncle	1.5-2.0 • 1.4-1.6	rough to undulate	Raw umber variation	distinct, sometimes fleshy ridges	prominent, sac-shaped	caruncle may function as elaiosome	rounded or low knobs
C. ziyaretensis	sub-globose to ovoid	2.2-2.5 • 1.7-2.0	finely to coarsely undulate	Mars Brown variation	distinct fleshy ridges, significantly extended into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded or low knobs
C. bowlesianus	probably ovoid but shape influenced by caruncle	1.5-2.0 • 1.1-1.5	smooth to partly undulate	Burnt umber variation	rather indistinct, merged into caruncle	very prominent as extension of main-body	caruncle may function as elaiosome	rounded or low knobs
C. calanthus	probably irregularly shaped but influenced by caruncle	4.1-4.7 • 2.9-3.2 (whole seed)	smooth	Raw umber variation	indistinct	very prominent as extension of main-body	caruncle may function as elaiosome	rounded
C. salurdagensis	sub-globose to ovoid, flattened at base	1.3-1.8 •1.2-1.5	rough without structure	Burnt umber variation	indistinct to distinct ridges	sac- to tongue-shaped	caruncle may function as elaiosome	rounded or little knobs
C. oreogenus	globose to sub-globose, often flattened at caruncle	2.3-2.7 • 2.2-2.7	rough to undulate	Raw umber variation	distinct fleshy ridges, significantly extended into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded or low knobs
***cancellatus*-group**								
C. cancellatus	ovoid to elongated	3.1-3.4 • 1.4-1.9	rough without structure	Burnt umber variation	distinct fleshy ridges merged into caruncle	extension of main-body, tongue- or sac-shaped, different color	caruncle may function as elaiosome	distinct knobs of different color
C. pamphylicus	probably ovoid but shape hidden by caruncle	1.7-2.2 • 1.5-2.0	coarsely undulate	Brown ochre with naples yellow variation	distinct, fleshy, extended into caruncle	very prominent as extension of main-body, rounded, tongue- or sac-shaped	caruncle may function as elaiosome	rounded or flat knobs
C. lycius	ovoid, often flattened at caruncle	2.7-3.2 • 1.8-2.3	rough with linear structures	Raw umber with yellow light (doubtful)	indistinct ridges, merged into caruncle	distinct, sac-shaped	caruncle may function as elaiosome	rounded or flat knobs
C. damascenus	globose to ovoid, rarely extended	2.1-2.7 • 1.4-1.9	finely undulate with linear structures	Raw umber with yellow ochre variation	distinct, often fleshy ridges, merged into caruncle	prominent, knob- or sac-shaped	probably present at opposite end of caruncle	this end of raphe may function as elaiosome

Table 4 (continued)

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
***cancellatus*-group** (continued)								
C. mazziaricus	ovoid	2.1-2.5 • 1.7-1.8	rough without structure	Raw umber with yellow ochre variation	distinct, fleshy, extended into caruncle	distinct, sac-shaped	probably present at opposite end of caruncle	knob- or sac-shaped, may function as elaiosome
C. *hermoneus*	globose to sub-globose	2.2-2.3 • 2.3-2.6	rough to undulate	Raw umber variation	distinct, fleshy, extended into caruncle	distinct, sac-shaped	caruncle may function as elaiosome	flat knobs
series *Biflori*								
C. biflorus	globose to sub-globose	0.9-1.1 • 0.8-1.2	rough without structures	Gold ochre	distinct ridges merged broadly into caruncle	distinct, sac-shaped, of darker color	caruncle may function as elaiosome	rounded, rarely tiny peaks
C. babadagensis	globose to sub-globose	1.9-2.0 • 1.7-2.0	rough without structure	Brown ochre with naples yellow variation	indistinct, often hardly visible	extremely prominent as extension of main-body, horn- or tongue-shaped, different colour	caruncle may function as elaiosome	rounded
series *Speciosi*								
C. speciosus	globose to sub-globose	1.8-2.1 • 1.8-2.0	rough without structure	Raw umber variation	distinct ridge, merged into caruncle	rather small, flat or peaky knobs	absent	little knobs or peaks
C. xantholaimos	sub-globose to ovoid	1.6-2.3 • 1.4-1.7	rough without structure	Burnt umber variation	mostly distinct fleshy ridge, merged into caruncle	rather small knobs or sacs	absent	tiny peaks
C. ilgazensis	globose to sub-globose, often somewhat irregular	1.7-2.2 • 1.8-2.1	mainly smooth	Burnt umber variation	distinct narrow and low ridges, merged into caruncle	indistinct or small peaky knobs	absent	rounded
C. pulchellus	sub-globose to ovoid	2.1-2.5 • 2.0-2.2	mainly smooth to rarely rough	Cadmium red purple variation	mostly distinct ridges, merged into caruncle	distinct, shortly tongue-shaped	absent	rounded or tiny peaks
without clear allocation yet								
C. crewei	globose to ovoid	1.7-1.8 • 1.6-1.7	finely undulate	Red umber with yellow ochre variation	distinct to prominent, often fleshy, merged into caruncle	very prominent, sac-shaped	caruncle may function as elaiosome	rounded or tiny knobs
C. chrysanthus cf.	globose to ovoid, sometimes irregularly so	1.5-1.9 • 1.3-1.7	rough without structure	Caput mort violet (mars) variation	distinct fleshy ridges, merged into caruncle	prominent, often as extension of main-body, tongue-shaped	caruncle may function as elaiosome	rounded or tiny peaks
C. melantherus	ovoid	2.0-2.4 • 1.3-1.6	smooth	Red ochre variation	prominent bright yellow, fleshy ridges, expanded into caruncle	prominent, often as extension of main-body, sac- to tongue-shaped, same color as raphe	caruncle may function as elaiosome	small knobs or tongues
C. nubigena cf.	shape of main-body not determinable because of extreme caruncle	3.9-4.3 • 1.7-1.8 (whole seed)	rough to coarsely undulate	Burnt umber variation	distinct ridges, merged into caruncle but often badly visible	very prominent as extension of main-body, rounded, tongue- or sac-shaped	caruncle may function as elaiosome	rounded or tiny peaks
C. coloreus	ovoid, flattened at caruncle	1.9-2.4 • 1.4-1.7	rough without structure	Mars Brown variation	rather indistinct ridges, merged into caruncle	distinct, sac-shaped	caruncle may function as elaiosome	rounded knobs of different colour
***punctatus*-group**								
C. weldenii cf.	globose to sub-globose	1.8-2.7 • 1.6-2.4	rough without structure	Brown ochre with naples yellow variation	distinct fleshy ridges, expanded into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded or knob-shaped

Table 4 (continued)

systematic position of taxon	seed shape (main body)[1]	seed size length • width[2] [mm]	testa surface condition[3]	seed colour[4]	raphe	caruncle	elaiosome	shape of seed-end at opposite side of caruncle
***punctatus*-group** (continued)								
C. pulchricolor	ovoid to irregularly shaped	1.9-2.7 • 1.8-2.1	rough without structure	Burnt umber variation	distinct ridges, merged into caruncle	prominent, mostly as extension of main-body, tongue-, horn- or sac-shaped	caruncle may function as elaiosome	rounded
C. alexandri	globose to ovoid, sometimes flattened at caruncle	1.9-2.2 • 1.7-1.9	rough without structure	Raw umber with yellow ochre variation	distinct fleshy ridges, expanded into caruncle	distinct, sac-shaped	caruncle may function as elaiosome	rounded
C. caelestis	sub-globose to ovoid	1.6-2.3 • 1.7-2.0	rough without structure	Raw umber with yellow ochre variation	distinct fleshy ridges, expanded into caruncle	distinct, sac- or tongue-shaped	caruncle may function as elaiosome	knob-shaped
C. punctatus	sub-globose to ovoid	1.9-2.3 • 1.8-2.2	coarsely undulate	Brown ochre with naples yellow variation	distinct to fleshy ridges expanded into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded or knob-shaped
C. sieheanus	sub-globose to ovoid, rarely flattened at caruncle	2.1-2.3 • 1.5-2.0	rough, often with linear structures	Red umber with yellow ochre variation	distinct fleshy ridges, expanded into caruncle	prominent, sac-shaped	caruncle may function as elaiosome	rounded
C. danfordiae cf.	globose to sub-globose	1.3-1.4 • 1.1-1.3	mainly smooth	Red ochre variation	distinct fleshy ridges strongly expanded into caruncle	very prominent, sac- or tongue-shaped	caruncle may function as elaiosome	rounded
C. leucostylosus	ovoid, flattened at caruncle	1.6-1.8 • 1.3-1.7	rough without structure	Mars Brown variation	rather indistinct, merged into caruncle	indistinct, knob-shaped	absent	knob-shaped

[1]according to main shapes defined in Tab. 3 (in necessary cases with sub-divisions).
[2]range of five typical seeds of good condition, other cases are mentioned (measurements of main seed body without caruncle, raphe, and sculptures at opposite site of the seed), measurements were calibrated at µm level then rounded to 0.1 mm, measured at a magnification of around 50 times.
[3]according to Fig. 4.
[4]definitions of Fig. 7.
*one seed, the other one shown cannot be evaluated because it is shrivelled.

They transport the seeds into their colony (as nutrient store), occasionally covering rather large distances from the "mother-plant". When the content of the elaiosome is eaten the ants leave the seeds in their stored places where they can germinate when the conditions become favourable. The whole procedure supports significantly the distribution of crocuses. An elaiosome is not present in every crocus species (Fig. 4, 5.1). If present it can be situated in different positions on the seed. In many cases the caruncle has the function of an elaiosome (*Crocus alatavicus,* Fig. 4, 5.2) or in some significant cases as in the *sieberi*-group the elaiosome is a bright golden-yellow sac-like attachment of fleshy texture to the raphe (strophiole) which gets rather skinny and membranous when dried (Fig. 4, 5.3). The absence/presence or kind of an elaiosome on a crocus seed can be used for distinguishing purposes. Large and sac-like caruncles are mostly of a bright yellowish colour and skinny texture and are especially supposed to function as an elaiosome.

The **opposite end of the caruncle** shows also considerable variety and different shapes. It is obviously another parameter of relevance for descriptions in some cases. The following shapes were found: The opposite end of the caruncle is rounded (Fig.4, 6.1), peaky (Fig. 4, 6.2), knob-like (Fig. 4, 6.3), sac-like (Fig 4, 6.4), or conical (Fig. 4, 6.5)

The **colour** of seeds is a very complex parameter. There are several reasons for this. The more important ones are as follows. The colour of *Crocus* seeds can vary dependent on age. Impressive examples are *C. caspius* (fresh greenish, old dark brown) and *C. atrospermus* (fresh red, old black). To get comparable results the seeds must be stored in a dry dark place at least for three month. Furthermore every light source has a different spectrum influencing the absorption and emission of wave-lengths from the testa which results in slightly different colours. As all the photographs were made under the microscope, a different spectrum to the sunlight had to be used. To overcome difficulties with different light sources, all photographs were made under constant conditions (including brightness) therefore resulting in colours relatively comparable to each other. On the seed surface different colours may occur in different parts so the colour sample of a seed was taken from the middle of the main-body of the original photograph using photo software. The results are shown in Figs. 5a-c. In the beginning of the colour investigation we wanted to compare these results with international colour-charts but we had to give this up quickly due to the fact that the testa colours are mostly inhomogeneous, which makes them not comparable with homogeneous standard colour charts. But the most problematic point is the "individually seen" colour of different spectators. After some trials with different persons in this direction we were able find someone whose eyes are trained to arrange different colours which often only differ in nuances. In this way it was possible to sort all occurring seed colours from "very dark" to "very bright" and according to their different colour nuances as shown in Fig. 6. A challenge was the definition of colours which was tried with several standard charts. It turned out that the "Old Holland Classic Oil Colour Paint Colour Chart" from "Broad Canvas" was most appropriate because of the continuous dark-bright variation of every colour. Finally every seed colour could be arranged into named groups as can be seen in Fig. 7.

Macroscopic seed descriptions

For general comparative purposes and to recognise possible similarities of seed morphology within molecular derived groups as well as dissimilarities between them all the seed descriptions of the investigated taxa are arranged according to the present phylogeny of the genus (Tab. 4). Seeds of infra-serial species seem to be often rather similar macroscopically. Also, as can be seen in the multi-focus photographs and in the descriptions of Tab. 4 even inside of phylogenetic groups some taxa have only slightly different descriptions. A detailed evaluation of the results as well as of their taxonomic value based on statistical assessments procedures is only useful together with the microscopic seed characters which will be presented in part two.

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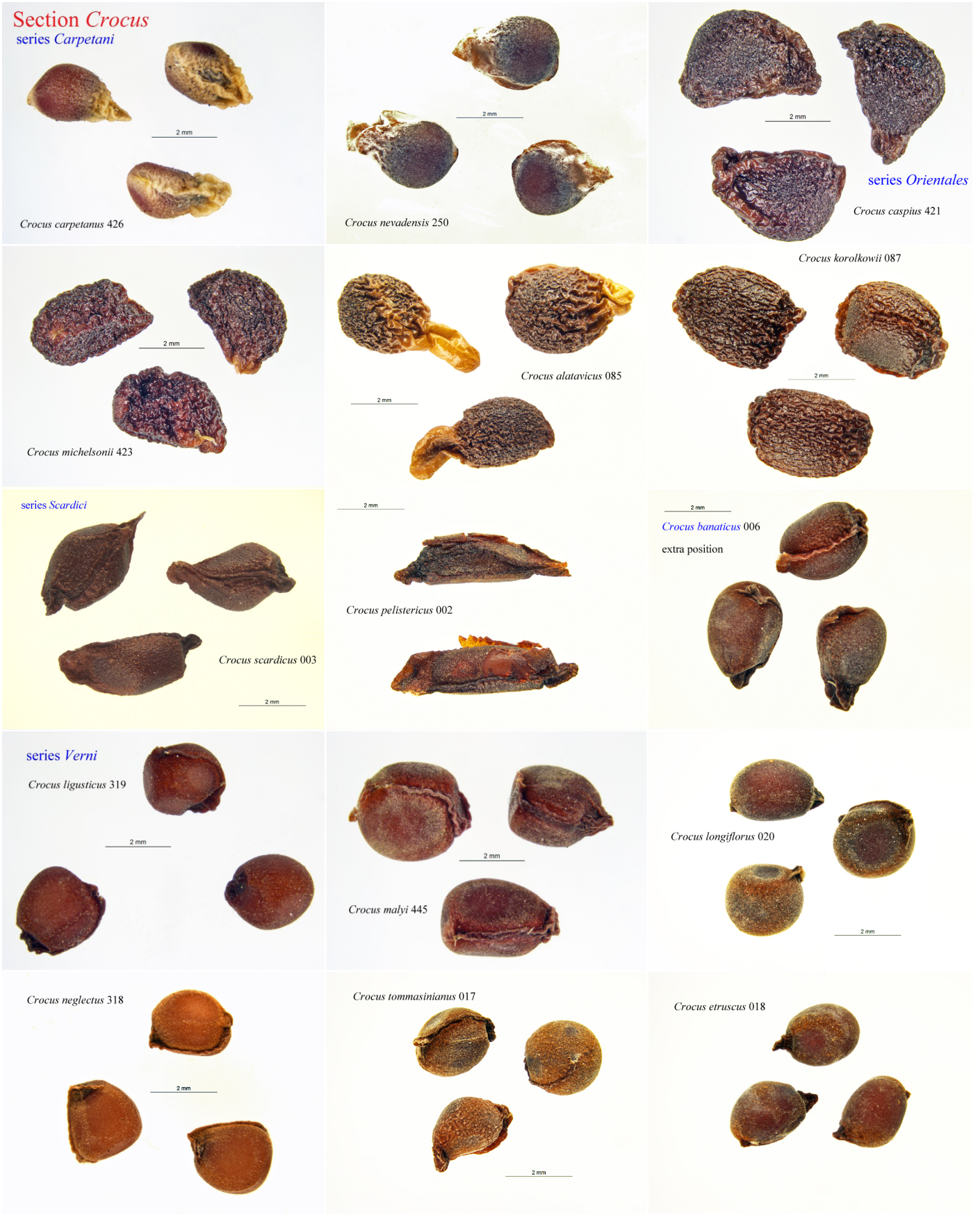

Fig. 2a: Multi-focus photographs of seeds in order of the recent phylogeny.

Fig. 2b: Multi-focus photographs of seeds in order of the recent phylogeny.

Fig. 2c: Multi-focus photographs of seeds in order of the recent phylogeny.

Fig. 2d: Multi-focus photographs of seeds in order of the recent phylogeny.

Fig. 2e: Multi-focus photographs of seeds in order of the recent phylogeny.

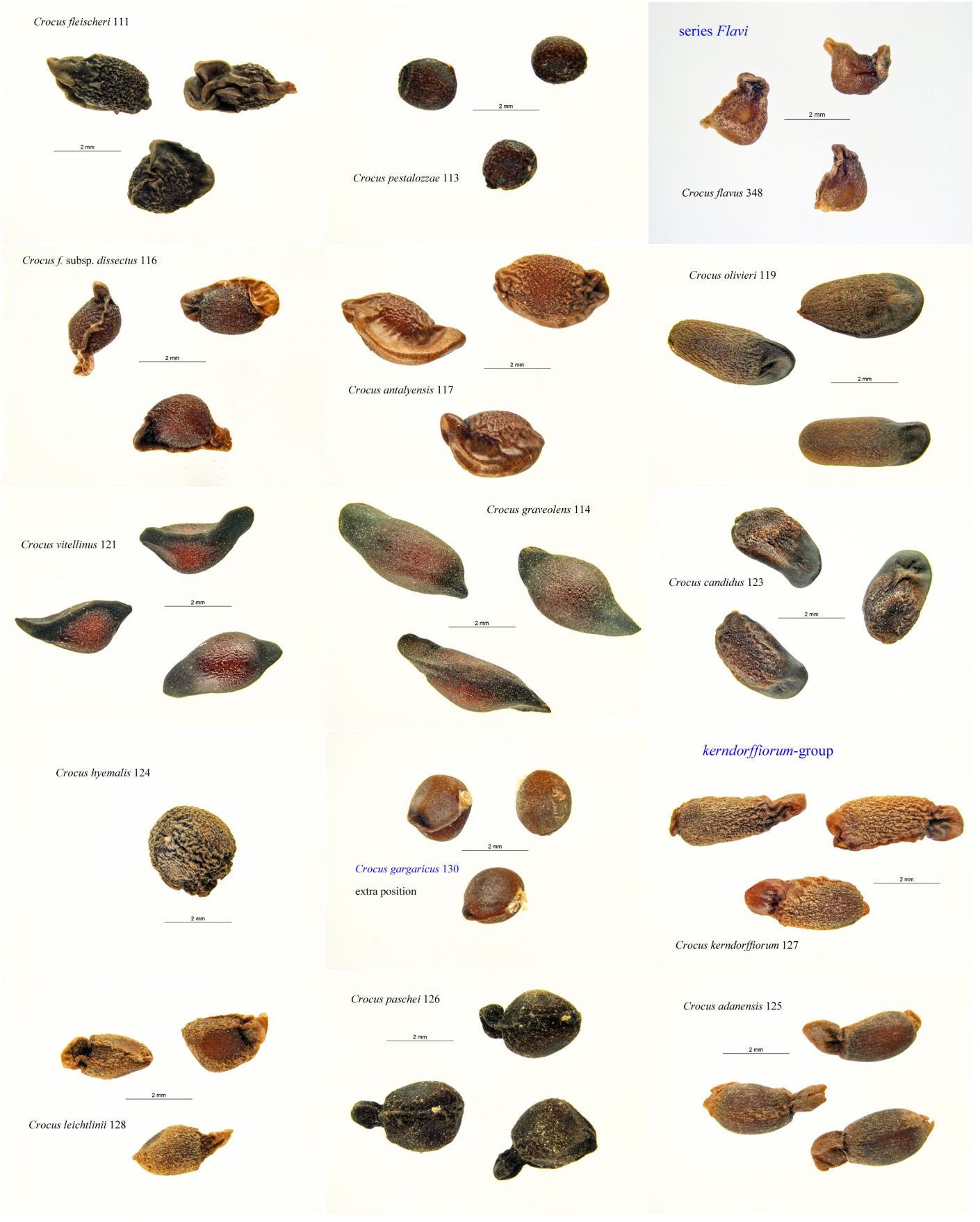

Fig. 2f: Multi-focus photographs of seeds in order of the recent phylogeny.

Fig. 2g: Multi-focus photographs of seeds in order of the recent phylogeny.

Fig. 2h: Multi-focus photographs of seeds in order of the recent phylogeny.

Fig. 2i: Multi-focus photographs of seeds in order of the recent phylogeny.

Fig. 2j: Multi-focus photographs of seeds in order of the recent phylogeny.

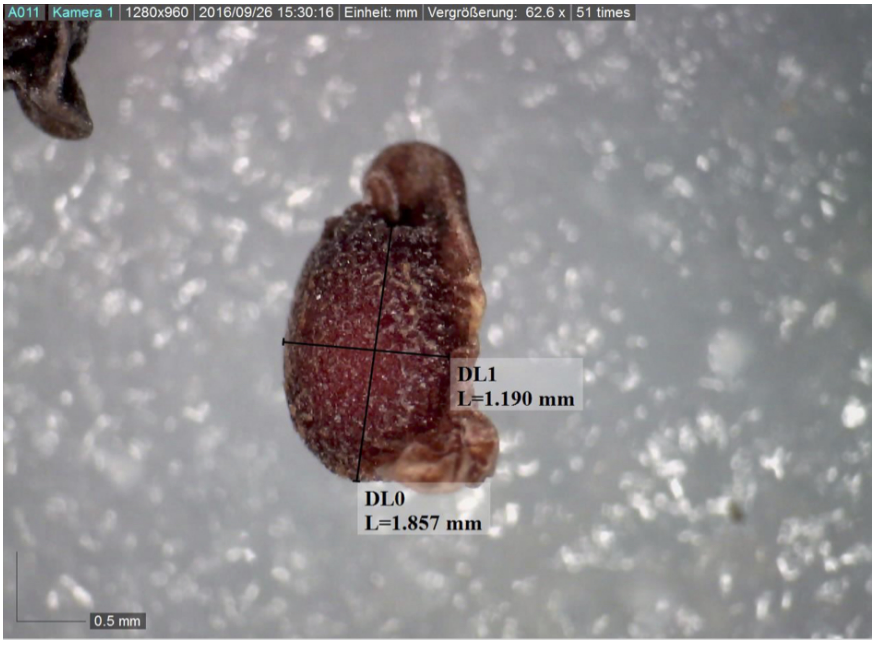

Fig. 3: Seed measures of *Crocus flavus* subsp. *dissectus*.

1.1 globose
1.2 ovoid
1.3 elongate
1.4 irregularly shaped (chestnut-like)
2.1 surface finely undulate
2.2 surface coarsely undulate
rough liear structured
2.4 surface rough without structure
smooth
3.1 raphe indistinct
raphe distinct
3.3 raphe prominent & winged
4.1.1 caruncle as extension of main-body
ends half-rounded
4.1.2 ends tongue-shaped
4.1.3 ends conical
4.2.1 caruncle indistinct
4.2.2 caruncle of different colour compared to main body
4.2.3 caruncle knob-shaped
4.2.4 caruncle sac-shaped
4.2.5 caruncle tongue-shaped
4.2.6 caruncle hood-shaped
4.2.7 caruncle horn-shaped
5.1 elaiosome absent
5.2 elaiosome present (as caruncle)
5.3 elaiosome present (attached to raphe)
6.1 seed end opposite to caruncle rounded
6.2 seed end opposite to caruncle peaky
6.3 seed end opposite to caruncle knob-like
6.4 seed end opposite to caruncle sac-like
6.5 seed end opposite to caruncle conical

Fig. 4: Macroscopic seed characters of *Crocus* arranged according to character definitions in Tab. 3.

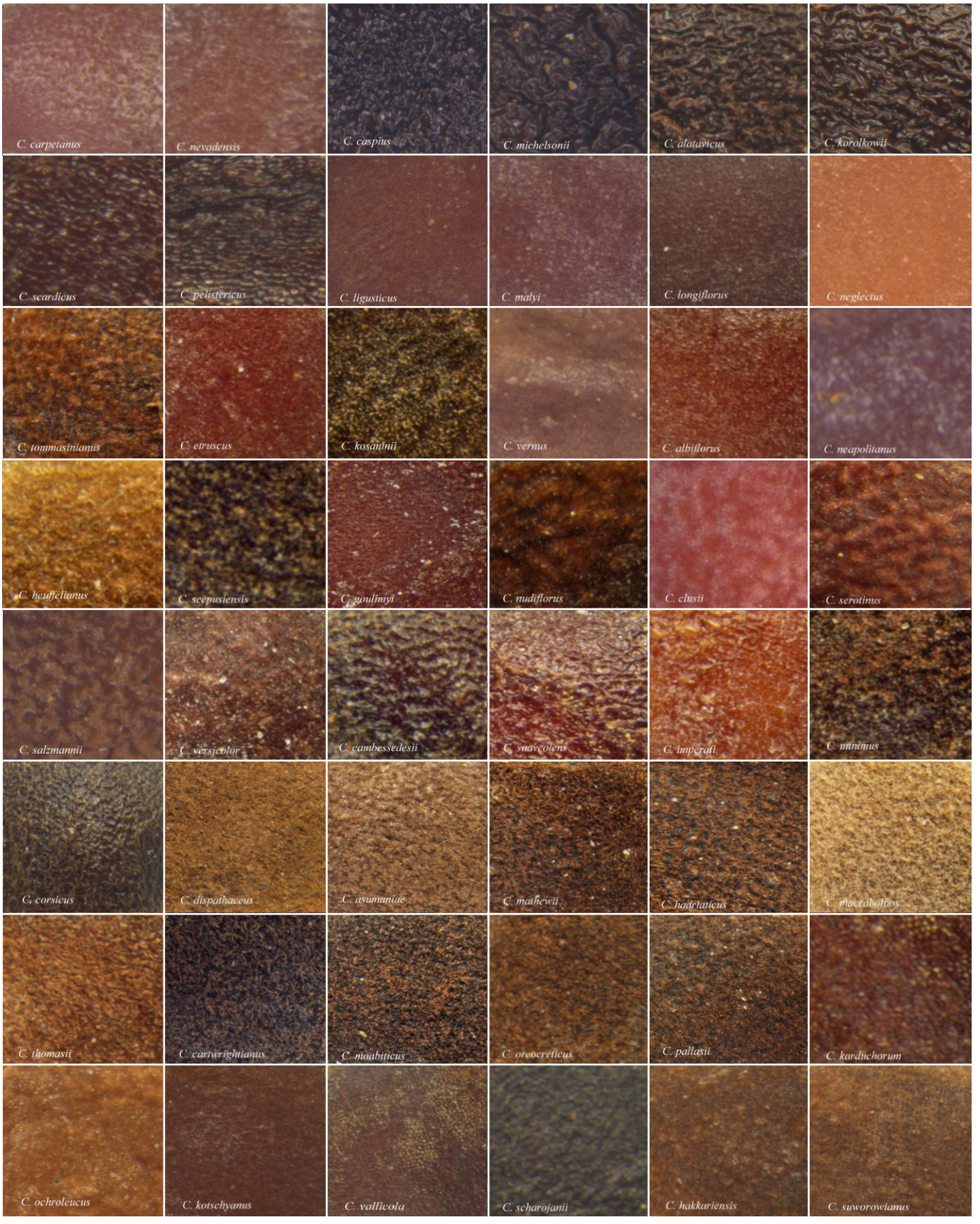

Fig. 5a: Colour variation and macroscopic surface condition of *Crocus* seeds arranged according to phylogenetic groups.

Fig. 5b: Colour variation and macroscopic surface condition of *Crocus* seeds arranged according to phylogenetic groups.

Fig. 5c: Colour variation and macroscopic surface condition of *Crocus* seeds arranged according to phylogenetic groups.

Fig. 6: Continuous seed colour-arrangement considering all different colour shades found in *Crocus* seeds sorted from “very dark” to “very bright”.

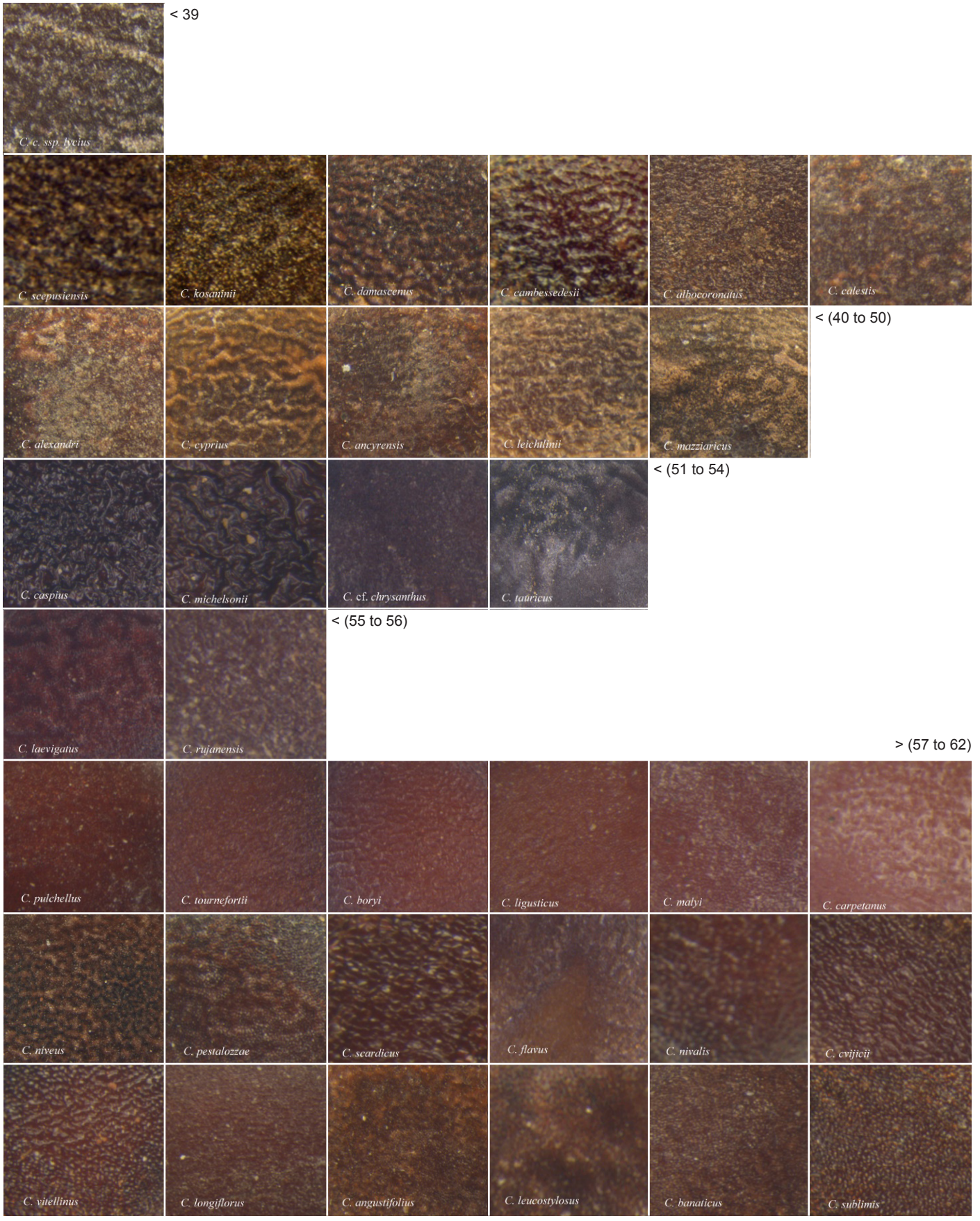

Fig. 6 (continued)

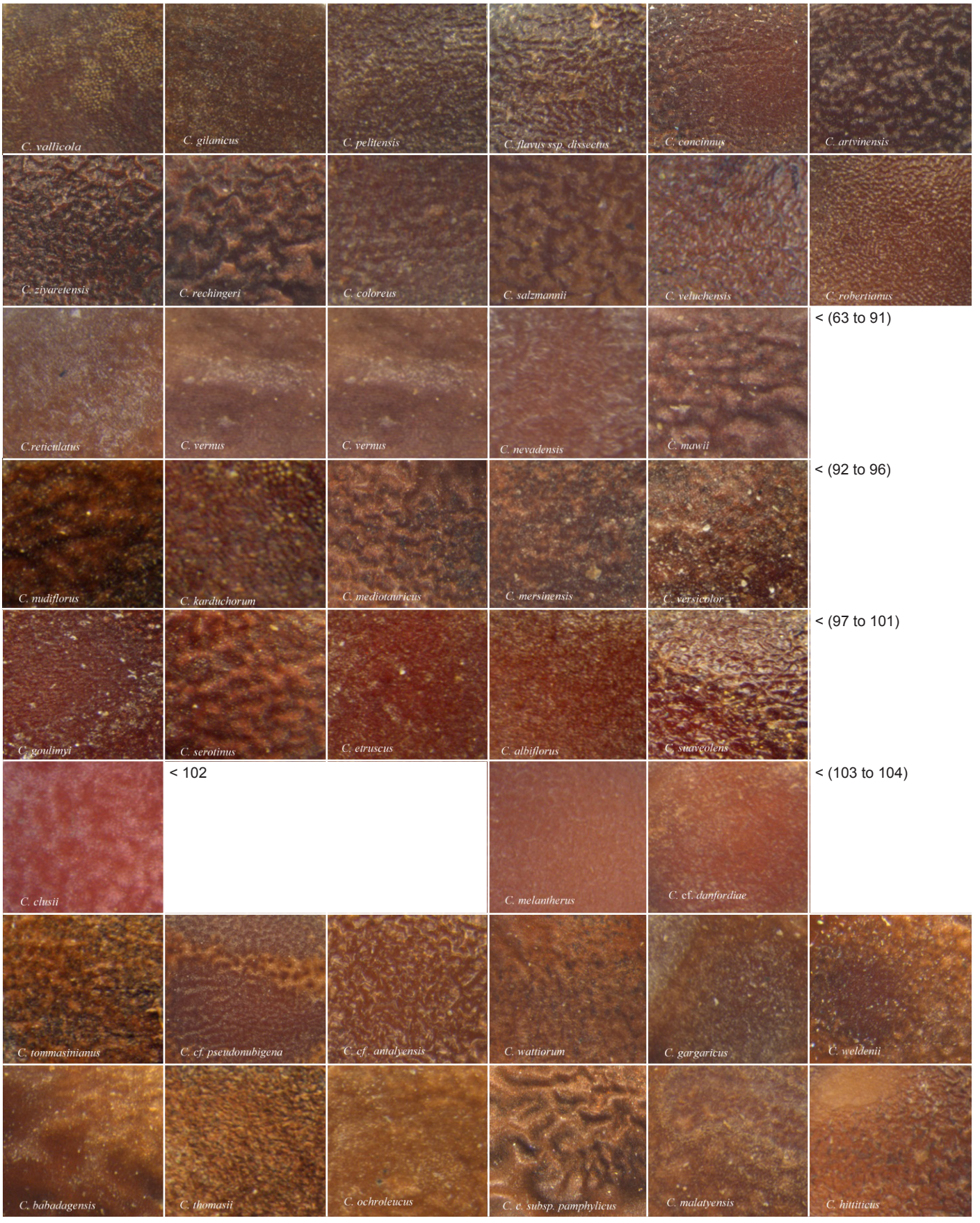

Fig. 6 (continued)

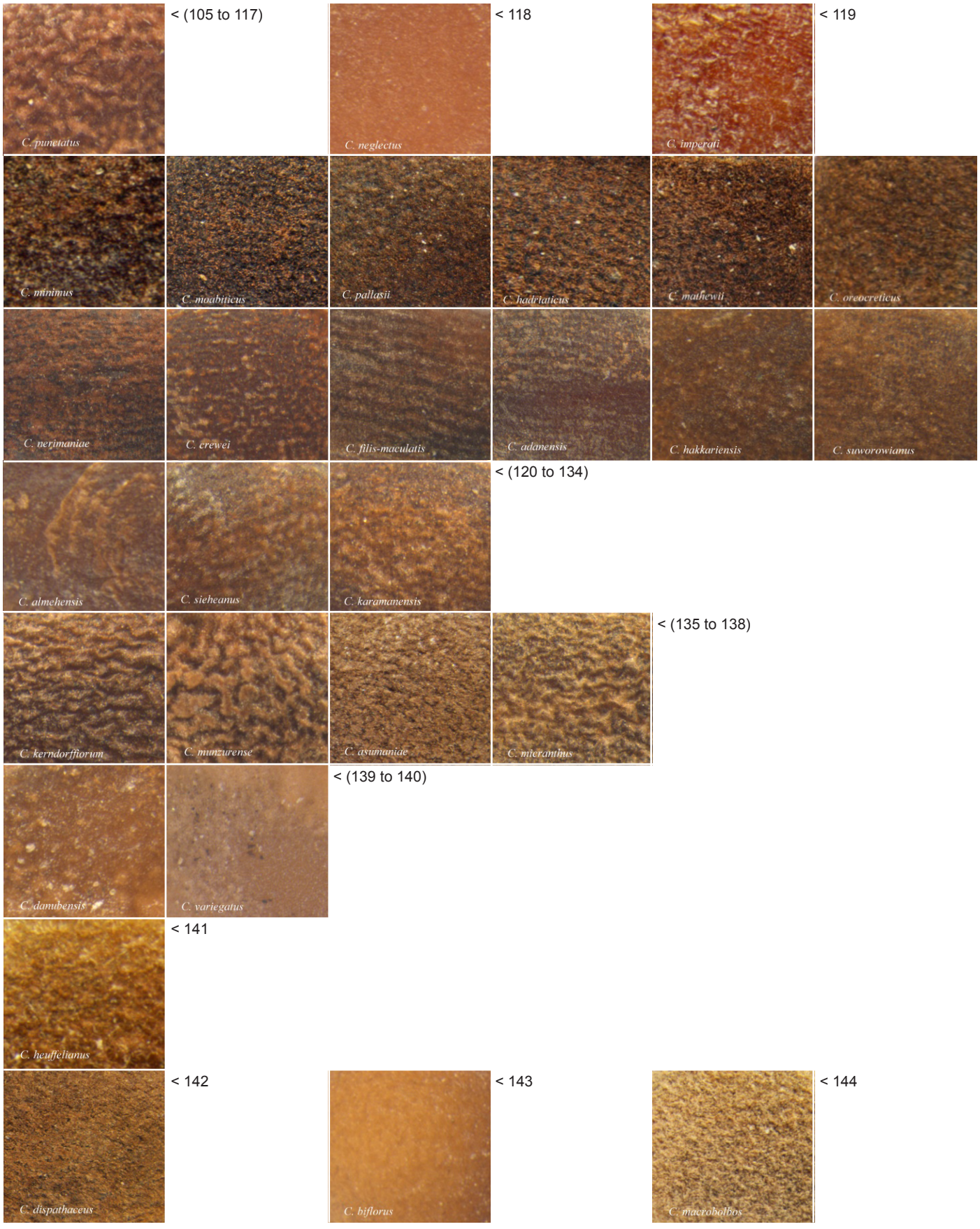

Fig. 6 (continued)

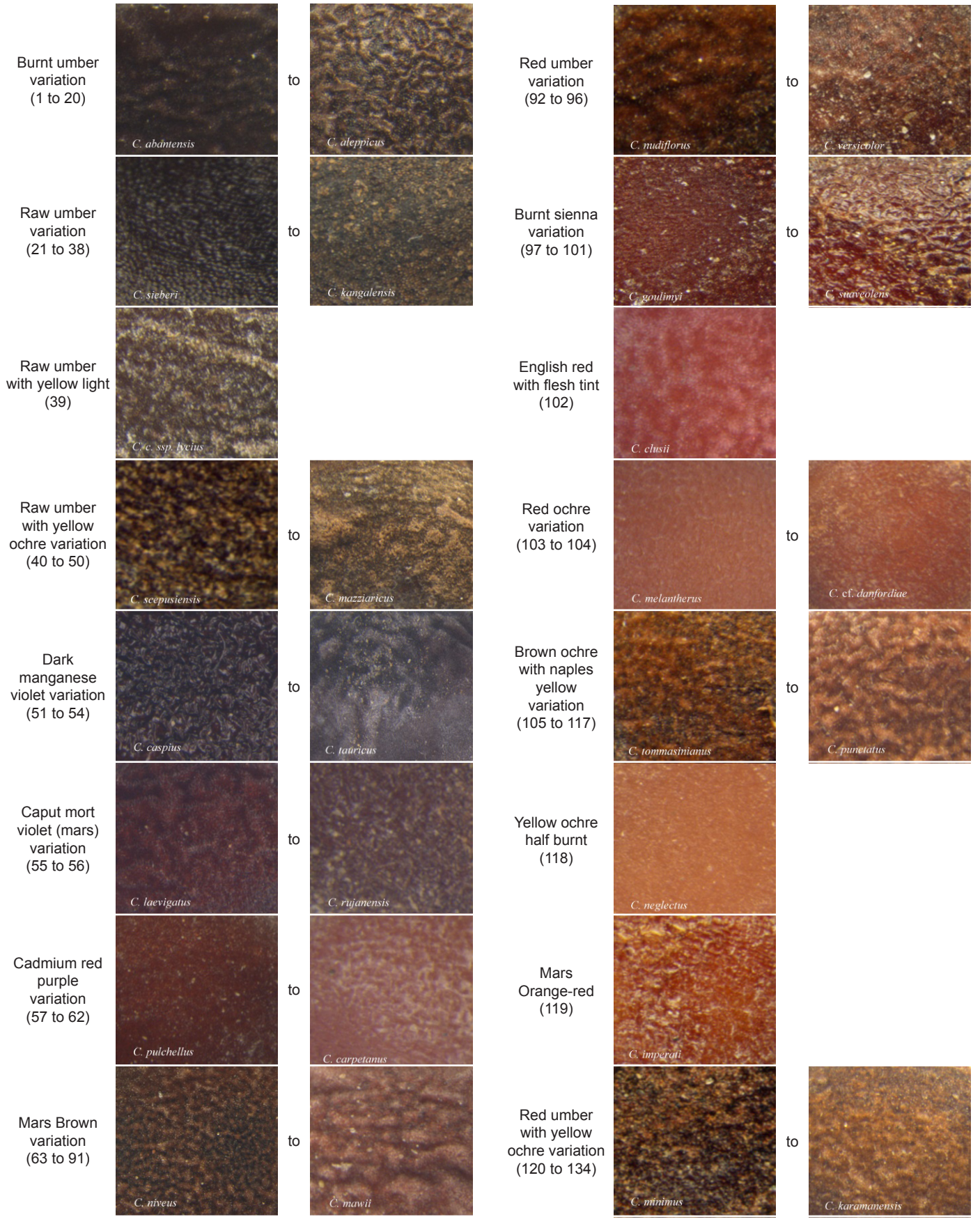

Fig. 7: Defined seed color groups according to the "Old Holland" color chart[1].

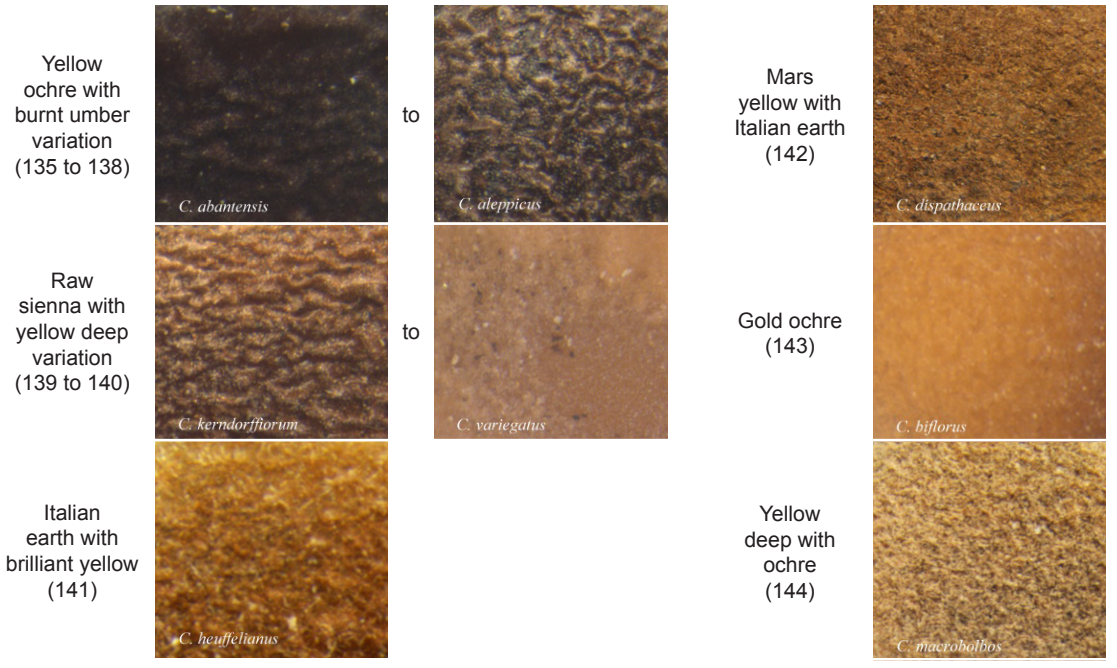

Fig. 7: Defined seed color groups according to the "Old Holland" color chart[1].

[1]numbers begin at top left row of Fig. 6, continue to the right and then start again the next row left and so on.